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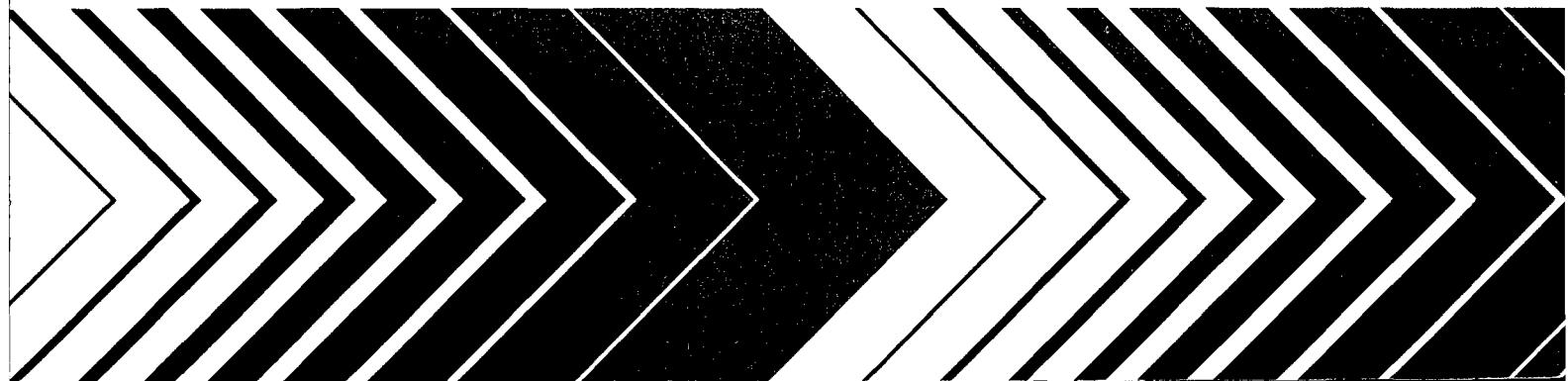
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# Life Cycle Assessment for Chemical Agent Resistant Coating

15 - 1996



# LIFE CYCLE ASSESSMENT FOR CHEMICAL AGENT RESISTANT COATING

By

Battelle Columbus  
and  
Lockheed-Martin Environmental

Contract No. 68-C4-0020

Project Officers

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## **Foreword**

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of material that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and carry out action leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to do research to define our environmental problems, measure the impacts, and search for solutions.

The National Risk Management Research Laboratory is responsible for planning, implementing, and managing research development, and demonstration programs. These provide an authoritative defensible engineering basis in support of the policies, programs and regulation of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund -related activities. This publication is a product of that research and provides a vital communication link between researchers and users.

This report describes a life cycle assessment on the painting, depainting and repainting of military vehicles with chemical agent resistant coating (CARC). A life cycle design approach that follows EPA's guidance manual includes consideration in the areas of environmental, performance, and cost requirements for the products and processes evaluated. Four specific final products associated with the painting, depainting, and repainting of military vehicles were used in the life-cycle assessment.

E. Timothy Oppelt, Director  
National Risk Management Research Laboratory

## **Abstract**

This project was sponsored by the Department of Defense Strategic Environmental Research and Development Program (SERDP) and conducted by the U. S. Environmental Protection Agency National Risk Management Research Laboratory (NRMRL). In support of SERDP's objective to develop environmental solutions that improve mission readiness for federal activities, this report was developed to determine the optimum materials and equipment for applying chemical agent resistant coating (CARC) to vehicles at the Army Transportation Center at Fort Eustis, VA. A life cycle assessment (LCA) was conducted to identify the performance, cost, and environmental impacts of various combinations of CARC materials and equipment. The variables for this study were the primer, thinner, CARC topcoat, and spray application equipment. Combinations of the variables were grouped to develop five alternatives. The recommended alternative would change the existing primer and application equipment, but retain the existing thinner and topcoat. This alternative would maintain required performance characteristics, achieve cost objectives, and result in low environmental impacts in relation to the other alternatives.

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## Acronyms

AG	alternative gun
AHP	Analytical Hierarchy Process
AP	acidification potential
BCF	bioconcentration factor
BG	baseline gun
BOD	biological oxygen demand
BTU	British Thermal Unit
CARC	chemical agent resistant coating
CAS	Chemical Abstract Service
CIS	Chemical Information Systems
CSD	Chemical Specialists & Development
DfE	design for the environment
DoD	Department of Defense
DOE	Department of Energy
EC	Expert Choice™
EPA	Environmental Protection Agency
FCI	fixed capital investment
FSC	Federal Stock Class
ft <sup>2</sup>	square feet
gal	gallon
GWP	global warming potential
HAP	hazardous air pollutant
HSDB	Hazardous Substances Databank
HV	hazard value
HVLP	high-volume, low-pressure
IRIS	Integrated Risk Information System
kw	kilowatt
lbs	pounds
LC <sub>50</sub>	lethal concentration, 50%
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact assessment
LCImA	life cycle improvement assessment
LD <sub>50</sub>	lethal dose, 50%
In	natural log
MEDLARS	Medical Literature and Analysis Retrieval System
MEK	methyl ethyl ketone
MIL-SPEC	military specification
MSDSs	Material Safety Data Sheets
NIINs	National Item Identification Number
NO <sub>x</sub>	nitrogen oxides
NRMRL	National Risk Management Research Laboratory
ODP	ozone depletion potential

P2	pollution prevention
Pb	lead
PE	purchased equipment
PES	Pacific Environmental Services
PM	particulate matter
POCP	photochemical oxidant creation potential
ppm	parts per million
PPOA	pollution prevention opportunity assessment
QSAR	quantitative structure-activity relationship
RD&D	Research, Design and Development
RTECS	Registry of Toxic Effects of Chemical Substances
SAR	structure-activity relationship
SERDP	Strategic Environmental Research and Development Program
SETAC	Society of Environmental Toxicology and Chemistry
SO <sub>x</sub>	sulfur oxides
SRI	Southern Research Institute
TE	transfer efficiency
TRI	toxic release inventory
VOC	volatile organic compound
WA	Work Assignment
WREAFS	Waste Reduction Evaluation At Federal Sites

## 1.0 Introduction

The research effort described in this report was conducted under cooperating programs of both the Department of Defense (DoD) and the Environmental Protection Agency (EPA). Among the shared objectives of the cooperators is demonstrating the effectiveness of analytical tools and environmental techniques to reduce environmental impacts and costs of operations while maintaining performance standards. This project was sponsored by the DoD's Strategic Environmental Research and Development Program (SERDP) and conducted by the EPA's Life Cycle Assessment (LCA) Research Team at the National Risk Management Research Laboratory (NRMRL).

### 1.1 Strategic Environmental Research and Development Program



SERDP was established in order to sponsor cooperative research, development, and demonstration activities for environmental risk reduction. Funded with DoD resources, SERDP is an interagency initiative between DoD, the Department of Energy (DOE), and EPA. SERDP seeks to develop environmental solutions that improve mission readiness for federal activities. In addition, it is expected that many techniques developed will have applications across the public and private sectors.

### 1.2 Life Cycle Assessment Research Program

Since 1990, NRMRL has been at the forefront of development of Life Cycle Assessment as a methodology for environmental assessment. In 1994, NRMRL established an LCA Team to organize individual efforts into a comprehensive research program. The LCA Team coordinates work in both the public and private sectors with cooperators ranging from members of industry and academia to federal facility operators and commands. The team has published project reports and guidance manuals, including "Life Cycle Assessment: Inventory Guidelines and Principles" and "Life Cycle Design Guidance Manual." The work described in this report is a part of an expanding program of research in LCA taking place under the direction of NRMRL in Cincinnati, Ohio.

### 1.3 DfE Life-Cycle Approach

A life-cycle design for the environment (DfE) approach that follows EPA's (1993a) guidance manual includes consideration of requirements in the following areas: environmental, performance, cost, cultural, and legal requirements. However, this report focuses on evaluation of the first three life-cycle design requirements. The life-cycle environmental evaluation and cost and performance information are based on data from the draft life cycle inventory (LCI) (Hendricks et al., 1995), pollution prevention opportunity assessment (PPOA) (Cavender et al., 1994), and supplementary information collected as part of the life cycle impact assessment (LCIA) and life cycle improvement assessment (LCImA).

The DfE approach is derived from a generalized process for product design, which begins with a needs analysis, defines product or process requirements, and identifies design solutions. When implemented as a DfE effort, the requirements assessment includes environmental elements specified as essential or desirable features. The design solutions then have a broader range of attributes than would be the case in a traditional analysis.

The procedures for interpreting LCI and LCIA results for the determination of improvement opportunities are not standardized. A multi-step process combining analysis of the baseline environmental data along with the possible engineering changes in the system was used to directionally identify promising options. The steps include:

- Definition of improvement objectives and constraints
- Translation of objectives into design/technology requirements
- Preliminary identification of options
- Determination of potential changes in system boundaries

These steps were conducted as part of the exercise to define the baseline and complete the inventory analysis and impact assessment. The alternatives assessment process, which constitutes the LCImA, then continues with the following elements:

- Identification of data needs for alternatives
- Generation of LCI/LCIA data for alternatives
- Generation of economic and performance data for alternatives, and
- Application of a decision support process for conducting tradeoffs analysis.

#### **1.4 Life Cycle Assessment for CARC**

NRMRL has developed projects to promote the integration of pollution prevention concepts into the design of systems. The purpose is to enhance performance, reduce logistics and maintenance requirements, reduce environmental and energy burdens and extend service life. Under this program, SERDP and NRMRL are focusing on painting and depainting operations for aircraft and military vehicles.

The U.S. Army's Transportation Center at Fort Eustis, Virginia provides educational and training services in military transport to Army personnel. Part of the mission at Fort Eustis is to paint, depaint and repaint military vehicles with a chemical agent resistant coating (CARC). The purpose of this project is to conduct an LCA for CARC operations at Fort Eustis which also considers cost and performance as described in EPA's life-cycle design manual (EPA 1993a).

A PPOA was conducted by Southern Research Institute (SRI) and PES at Fort Eustis to evaluate waste reduction opportunities associated with CARC painting and depainting operations (Cavender et al., 1994). The PPOA was part of the Waste Reduction Evaluations at Federal Sites (WREAFS) program and involved identification and evaluation of new technologies and techniques for reducing waste generation from CARC painting/depainting operations at Fort Eustis. The advantages and disadvantages of the base case and each P2 option are discussed. As in the case of most P2 studies, this PPOA only considered the use stage (depainting/painting) of the CARC life cycle. The PPOA was used to establish the potential options for the LCA.

A draft LCI was prepared by Pacific Environmental Services (PES) to provide a baseline of environmental and utility data that describes the production of components for the CARC painting/depainting system (i.e., topcoat, primer, thinner, and blast media), their raw materials, paint application and depainting, and disposal of spent CARC and blast media (Hendricks, et.al., 1995). The LCI baseline was revised to account for actual operations at Ft. Eustis and additional impact

information was included to complete the LCA. The LCIA and LCI<sub>m</sub>A were prepared according to EPA's LCA guidance document (EPA, 1993b) and the Society of Environmental Toxicology and Chemistry (SETAC 1991, 1993, and 1994) framework documents. This document contains a revised and summarized version of the LCI data along with the LCIA and LCI<sub>m</sub>A results.

### **1.5 CARC System Improvement Potential**

Within the established environmental criteria for the LCA, the baseline CARC system improvement potential appears to be greatest in the relative environmental impact contribution to global warming. However, this does not imply that CARC is a major contributor to this issue on an absolute basis. Somewhat less important are the regional scale impacts of photochemical smog and the aggregated indicators associated with toxicity potential. Alternative formulations emitting less of these constituents throughout the life cycle coupled with application practices that increase the efficiency of material usage (translating back up the life-cycle stages due to lower contributions per functional unit) are the most attractive.

However, the environmental aspects of CARC painting must be balanced with economic and performance aspects. It may be possible to conceive of a system where the coating is transferred with 100% efficiency through the use of no solvent at all (a powder coating for example). Although such a system may be a long-term R&D goal, its performance could not be guaranteed according to current military specifications (MIL-SPECS) and its cost may be prohibitive. Considering that operating labor and overheads represent more than half the baseline costs, alternatives that decrease the human input at the expense of modest increases in material or variable operating costs (material costs, electricity, and supplies represent about 25% of the total baseline costs) would be an overall improvement, especially if there were corresponding performance and environmental benefits.

The assessment of CARC alternatives is intended to identify and evaluate alternatives that are able to be implemented with a reasonable level of institutional, logistical, and operational challenges and within a short-term time frame. Therefore, it was decided that certain performance and cost constraints should be imposed as preliminary assessment thresholds. Identification of CARC systems that are improvement candidates on all three assessment dimensions (environmental, performance, cost) were constrained to those that currently provide acceptable performance (i.e. that are MIL-SPEC compliant), that are cost-competitive, and reduce environmental impacts. Systems considered to be attractive included various combinations of CARC topcoat, primer, and thinner, having different environmental properties than the baseline, as well as application methods and tools that potentially could increase materials use efficiency and decrease the time involved for painting operations. Equipment and technology to implement the improvements was also a consideration.

Application of the cost and performance thresholds resulted in a matrix of alternatives to be considered. The alternatives shown in Table 1-1 include permutations of alternative primer, thinner, and application technology (spray gun). Additional technology-related options appeared to be site-specific (e.g., spray booth configuration, filtration systems, and material storage, and were not considered separate alternatives). Similarly, the blast medium and technology (aluminum oxide) was considered both cost-effective and environmentally acceptable and was not subject to evaluation.

Table 1-1. CARC Systems for Evaluation in LCImA

CARC Systems Evaluated	CARC Topcoat <sup>(a)</sup>	Primer <sup>(b)</sup>	Thinner <sup>(c)</sup>	Topcoat Spray Gun <sup>(d)</sup>
1 (Baseline)	BC	BP	BT	BG
2	BC	AP	BT	BG
3	BC	BP	BT	AG
4	BC	AP	BT	AG
5	BC	BP	AT	BG
6	BC	AP	AT	BG

(a) BC = Baseline CARC Topcoat, MIL-C-53039A, Hentzen 08605GUZ-GD, 1-part urethane

(b) BP = Baseline Primer, MIL-P-53022, Niles 2-part epoxy, solvent thinned; AP = Alternative Primer, MIL-P-53030, Deft 2-part epoxy, water thinned

(c) BT = Baseline Thinner, MIL-T-81772B, CSD; AT = Alternative Thinner, Fed. Std. A-A-857B (used by Fort Eustis, but not evaluated by in LCI)

(d) BG = Baseline Gun, high volume, low pressure (HVLP) spray gun (thinning of topcoat required); AG = Alternative Gun, turbine HVLP spray gun with increased transfer efficiency relative to conventional HVLP gun.

## **2.0 Life Cycle Inventory**

To fully account for all impacts of the CARC operation, a complete evaluation must be made of the raw materials used, energy required, water used, and the generation of atmospheric emissions, solid waste, waterborne waste, and hazardous waste. A baseline should incorporate inputs and outputs from every operation used, from processing the basic raw materials through all operations involved in taking the material from the earth and disposal of the residue material back to the earth. To be practical and useful, a baseline must reflect the reality of the process as it is currently practiced.

### **2.1 LCI Scope and Limitations**

The initial phase of the life cycle inventory (LCI) consisted of studying available information on the CARC application and depainting processes and conducting an intensive, three-day site survey, literature search, and phone survey of major Army installations. Using the information obtained from the site survey, literature survey, and telephone contacts with the major U.S. Army facilities, a scoping document was prepared. The scoping document identified uses of CARC, the CARC product manufacturers, the primers and the thinners used in CARC systems, the blasting media used in the removal of CARC systems, and the types of CARC application and depainting techniques used.

The scoping document and input from EPA's NRMRL personnel were used to identify the specific products (the CARC, the primer, the thinner) to be addressed in the LCI. The specific application and depainting techniques to be investigated were also selected. The recommendations were based mainly on the products and techniques being used at Fort Eustis. A one-component topcoat is used as the final CARC layer to protect military vehicles from chemical warfare agents, primarily because it is more resistant to penetration by these chemical agents than alkyd paints. CARC paint does not absorb these substances, while alkyd paints absorb these toxic chemical agents and slowly release them. Also, CARC can last up to four times longer than alkyd paints. The only CARC topcoat used at Fort Eustis is MIL-C-53039A produced by Hentzen Coatings under the name 383 Green Zenthane.

Primers are applied to the surface of military equipment after depainting and surface preparation, in order to provide anticorrosive properties and adhesion of the topcoat. The CARC primer used at Fort Eustis and most other military installations is MIL-P-53022, a two-component epoxy primer. The brand used at Fort Eustis is produced by Niles Chemical Company and was chosen for the baseline LCI. The two-component epoxy primer is prepared for application by mixing four parts of Part A with one part of Part B. Once the primer is dry, a one-component CARC topcoat is applied. Both the primer and topcoat are applied with a high-volume, low-pressure (HVLP) spray gun.

A thinner is used to dissolve, dilute, suspend, or change the physical properties of other materials. At most Army bases except Fort Eustis, thinner MIL-T-81772 is used to dilute CARC and primer, in order to enhance ease of application, and to control the coating drying rate. Thinner MIL-T-81772 was used for the baseline LCI due to its wide-range use at Army facilities (Table 2-1). Thinner is also used prior to CARC painting to remove dust and grease from the vehicles that may

interfere with proper paint adhesion. Fort Eustis used a thinner that is not recognized specifically as a CARC thinner until 1995. Checks with Fort Eustis determined they preferred the characteristics of the thinner they were using (A-A-857B); they claimed it performed better in the hot, humid weather found at Fort Eustis. However, Fort Eustis and Fort Campbell were contacted in 1996 and both facilities had stopped use of A-A-857B. Based on the telephone survey conducted, 11 of the 13 Army facilities contacted used another thinner (MIL-T-81772) which according to painting instructions of Department of the Army is the applicable solvent for the CARC used at Fort Eustis (MIL-C-53039A).

Since aluminum oxide is used as a blasting medium at Fort Eustis to remove CARC, it was selected for the baseline LCI. It is preferred over other blasting materials for the depainting process because of its high efficiency and low cost. Aluminum oxide is extremely hard and the crystal surface is covered with sharp angles, which makes it an ideal blast media for the removal of CARC from steel surfaces.

**Table 2-1. Various CARC, Primers, and Thinners Used at Major Army Installations**

U.S. Army Installations	State	CARC used			Primer used			Thinner used		
		MIL-C-53039	MIL-C-46168	MIL-C-22750	MIL-P-53022	MIL-P-53030	MIL-P-23377	A-A-857B	MIL-T-6095	MIL-T-81772
Anniston Army Depot	AL		X	X	X					X
Corpus Christi Army Depot	TX	X	X	X	X		X			X
Fort Benning	GA	X								X
Fort Bliss	TX	X					X			X
Fort Bragg	NC	X				X			X	
Fort Campbell	KY	X	X					X		X
Fort Devens	MA	X				X				X
Fort Eustis	VA	X			X			X		
Fort Hood	TX	X			X	X	X			X
Fort Knox	KY	X				X				X
Fort Lewis	WA	X								X
Red River Army Depot	TX	X	X	X	X					X
Fort Riley	KS	X								X

The products and techniques evaluated for the LCI were:

- CARC: MIL-C-53039A
- Primer: MIL-P-53022
- Thinner: MIL-T-81772
- Blasting Media: Aluminum oxide
- Blasting Technique: high pressure air blasting
- Painting Technique: HVLP spray painting

Additional limitations in scope were used to streamline the LCI. The study focused on evaluating the main process reactions and excluded the low concentration ingredients (less than 1 percent) and catalysts used in the process reactions. It was assumed that ingredients used in small concentrations have small environmental impact in the life cycle.

## 2.2 LCI Methodology

In developing the LCI, all of the principal ingredients used to produce the final products were identified. The specific chemicals were identified using Material Safety Data Sheets (MSDS) provided by the manufacturers. Literature research was then conducted to identify the processes used to make the principal ingredients and to identify the raw materials. This process was repeated until every raw material was traced back to a fundamental precursor (i.e., one identified as coming from the earth as an ore or a petroleum product). Appendix A contains process flowsheets for the production of each of these final products, and Appendix B contains the MSDSs.

Each process was reviewed to determine the process inputs and the outputs. Process inputs include raw materials, water, and energy (i.e., electrical, natural gas (as fuel<sup>a</sup>), oil and coal). Outputs include the end product atmospheric emissions, waterborne waste and solid waste. Atmospheric emissions are the total for all pollutant types, including criteria pollutants<sup>b</sup> and hazardous air pollutants (HAP). Solid waste totals include hazardous and non-hazardous waste streams.

## 2.3 LCI Data Development

For each manufacturing process in the life cycle, data were required for raw material usage, utility requirements, and waste generation. Many manufacturers would not divulge information, because they were suspicious about unsolicited attempts to obtain proprietary process information. Secondary sources of data, such as industry reports, EPA documents, and magazine articles are available but vary in quality, completeness and timeliness. In general, chemicals produced in large quantities tended to have better quality and more complete information. Where primary process information was missing, streamlining measures were taken, and engineering estimates and assumptions were made. With this approach, it was possible to develop an "order-of-magnitude" estimate for the CARC LCI.

A typical search for data began by consulting general reference books on industrial chemical production processes such as Kirk-Othmer *Encyclopedia of Chemical Technology* or the *Encyclopedia of Chemical Processing and Design*. These sources often provided the necessary information, such as the process descriptions, raw materials consumption or utilities requirements, generally in the form of industry averages. The next level of the search involved resources on particular subjects such as the *Handbook of Petrochemicals and Processes*, *The USEPA's Industrial Process Profiles for Environmental Use*, or the *Environmental Sources and Emissions Handbook*. Again, the data were given in industry averages or averages from a number of monitored plants.

Searches for reports, articles or other sources of information were undertaken in an attempt to fill remaining gaps in the data. These searches sometimes yielded EPA reports, EPA contracted reports, or industry trade magazine articles. Information published after 1974 was considered sufficiently current.

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<sup>a</sup> Natural gas used in manufacturing is shown as a raw material, not as an energy input.

<sup>b</sup> Criteria pollutants are volatile organic compounds (VOCs), sulfur oxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), particulate matter (PM), inhalable particulate matter (PM<sub>10</sub>), carbon monoxide (CO), and lead (Pb).

## **2.4 LCI Baseline Revisions and Enhancements**

As part of the scoping activity for the LCIA, it was determined that several of the chemical components in the CARC life cycle described in the draft LCI (Hendricks et al., 1995) could be revised to fill in missing data or to provide more recent data on the manufacturing processes. Chemicals identified as most important for collection of additional LCI data were adiponitrile, cobalt chromite green, hexamethylenediamine, magnesium ferrite, phosgene, sodium cyanide, and sodium dichromate. Second tier chemicals included butyl acetate, butyl alcohol, and methyl isoamyl ketone. Additional chemicals derived closely from the crude oil and natural gas refining processes were not included in this ranked system, because they are part of the crude oil and natural gas extraction and refining models incorporated into the inventory model. This included aromatic 100, carbon monoxide, hydrogen, and propane.

Emissions for electrical production, crude oil refining, and natural gas production were taken from Battelle's LCI databases. The electrical production model calculates the pollutant loadings for the national electrical grid based on the fractions of power created from coal, hydrocarbons, nuclear, hydropower, wind, etc. The crude oil and natural gas models included detailed data on many of the primary refinery chemicals such as hydrogen, propane, aromatic 100, etc.

The next best readily available source for emissions data was to determine manufacturers of the chemicals of interest in Southern Research Institute's (SRI) (1993) *1993 Directory of Chemical Producers* and cross reference the manufacturer with 1993 Toxics Release Inventory (TRI) emission data. 1993 was the latest year for which both SRI and TRI data were both available. Production tables were available in the SRI directory for several chemicals of interest to the CARC study, thus allowing direct calculation of the emission rates per pound of product production.

The chemical producers listed in the SRI directory often produced several chemicals. Specific plants were selected for their production of only the chemical of interest of a small number of related products, thus minimizing the need for extensive allocation of the individual TRI facility emissions. Phosgene and sodium cyanide could be taken directly from the combination of the SRI/TRI data.

Hydrogen is produced from propane feedstock or as a co-product of chlorine/sodium hydroxide production. Analysis of the chlorine/sodium hydroxide manufacturing process required allocation of the emissions on a mass basis, thus allocating only a fraction of the emissions directly to the hydrogen production.

Adiponitrile and hexamethylenediamine production was more complicated in the selection of a plant to analyze and calculate the allocation of the emission streams. An analysis was performed on the SRI data to determine the relevant chemicals to the adiponitrile and hexamethylenediamine production processes and eliminate the unrelated process streams. TRI reportable releases were allocated on a mass basis to the appropriate process scheme.

Three of the butylated organic chemicals were analyzed together from the SRI/TRI data due to the close interlinkage of the processes as butyl aldehyde is a feedstock for the butyl alcohol process and butyl alcohol is a feedstock for the butyl acetate process with the addition of glacial acetic acid. The results were compared with the data existing in the model for completeness and consistency.

Several of the chemicals did not have production data to allow for proper emissions allocation on a per pound basis (e.g., sodium dichromate) and some of the organic chemicals were made in plants producing such a tremendous variety of chemicals that allocation would require an extensive understanding of the specific facility (e.g., methyl isoamyl ketone produced by Tennessee Eastman).

In addition, no emissions data were obtained for the production of isopropyl alcohol and butylcellosolve. Thus, the LCI data exclude emissions from manufacturing of these four chemicals.

Several chemicals were referenced in the *Merck Index* (Merck, 1983) and Aldrich Chemical Company's (Aldrich, 1992) *Catalog Handbook of Fine Chemicals* to other literature references. Energy requirements and emissions for the pigments cobalt chromite green and magnesium ferrite proved difficult. Data obtained could not be fit into the model. Cobalt chromite green was referenced by Merck (1983) to Gmelin's (1932 and 1961) *Handbook of Inorganic Chemistry*, printed in German. The process description indicated that airborne pollutants were the most common, but did not quantify the individual chemical pollutants which would then pass through various modern emission control devices.

Chemicals often may be manufactured in several ways. It was assumed the process diagrams (Appendix A) represented the typical method of manufacture of a given chemical and did not necessarily represent the documented process for each chemical in the CARC production process. Whenever possible, this same production methodology was utilized by examining the most common commercial production method(s). One exception was in the production of hydrogen, which in order to obtain readily separable data, used a caustic soda production process in which hydrogen is a co-product rather than the more common hydrocarbon derivation.

## 2.5 LCI Functional Unit

One of the first requirements during scoping activities for an LCA is the selection of a functional unit, so that resource use, energy use, and environmental releases from different life-cycle stages, or for different alternatives, can be expressed in the same units for comparative purposes. For the draft LCI, the functional unit selected was 1,000 gallons of CARC used. Paint application and depainting data were developed in units per 1,000 gallons of CARC used, which is slightly less than CARC produced due to spills and discarded old paint.

As part of the revisions and enhancements to the LCI data, this functional unit was reevaluated. Since the important requirement for any type of paint is the amount of materials (e.g., primer, thinner, and topcoat) required to produce a good finish over a specific area, 1,000 square feet ( $\text{ft}^2$ ) was selected as the appropriate functional unit. Thus, quantities of materials required or emissions released from any process in the CARC life cycle are expressed relative to a functional unit of 1,000  $\text{ft}^2$  of painted surface. In the LCImA all alternatives are compared on an equivalent functional unit basis with adjustments made to the amounts of material, labor, and capital associated with each option required to paint one functional unit of surface.

## 2.6 LCI Data

The revised baseline LCI results are provided in Appendix C. The tables in this appendix are organized by the following inputs and outputs to the CARC life cycle: Resource and Energy Consumption, Air Emissions, Wastewater Emissions, and Solid Wastes. The totals for each resource or emission are further divided by (1) Raw Material Extraction plus Materials Manufacture Stages and (2) Use/Reuse/Maintenance Stage plus Disposal (depainting/painting activities at Fort Eustis). All data are reported in the quantity per functional unit (1,000  $\text{ft}^2$  of CARC painted surface). These LCI data are the basis for the LCIA and LCImA results.

## 3.0 Parameters Evaluated

### 3.1 Inventory Analysis

The inventory analysis used for the LCI consists of the inventory for the baseline CARC system and the inventories for each of the five alternatives. The percent compositions of the baseline topcoat, baseline and alternative primers, and baseline and alternative thinners are listed in Tables 3-1, 3-2, and 3-3.

Table 3-1. Percent Composition of Baseline CARC Topcoat

CHEMICAL CONSTITUENTS	MIL-C-53039A (Hentzen 383 Green Zenthane, 08605GUZ-GD) (%)
Methyl Isoamyl Ketone	23.8
Magnesium Ferrite Pigment	3.9
Aromatic Hydrocarbons <sup>(a)</sup>	1.5
Butyl Acetate	1.2
VM&P Naptha	4.8
Xylene	2.0
Cobalt Chromite Green Spinel Pigment	3.9
Trivalent Chrome	6.9
Hexamethylene Diisocyanate	26.0
Diatomaceous Silica Pigment	26.0
<b>TOTAL</b>	<b>100</b>

<sup>(a)</sup> Mix of C8s to C10s

Table 3-2. Percent Composition of Baseline and Alternative Primers

CHEMICAL CONSTITUENTS	BASELINE (Niles <sup>(a)</sup> , 2-part epoxy, solvent thinned)		ALTERNATIVE (Deft, 2-part epoxy, water thinned)	
	53022A, 4-part <sup>(b)</sup> (%)	53022B, 1- part (%)	53030A, 4- part <sup>(b)</sup> (%)	53030B, 1- part (%)
Epoxy resin solids	22	23	16.03	71.17
Proprietary ingredients		2	0.10	0.06
TiO <sub>2</sub> <sup>(c)</sup>	20		33.96	
Extenders (Pigment) <sup>(c)</sup>	18		27.85	
Xylene		11		
n-Butyl Acetate	26			
MIBK	2	28		
Zinc Phosphate	4			
Diethylenetriamine		8		
2-Ethoxyethanol		11		
n-Butyl Alcohol	8	17	10.83	
Aromatic hydrocarbon			11.26	4.13
Nitroethane				24.64
<b>TOTAL</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

(a) Niles does not manufacture Mil-P-53030

(b) Note: The 4:1 mixture has not been pro-rated

(c) MSDS reports 38% proprietary ingredients, which were assumed to be divided between TiO<sub>2</sub> and pigment extenders, respectively, as 20% and 18%.

Table 3-3. Percent Composition of Baseline and Alternative Thinners

CHEMICAL CONSTITUENTS	BASELINE (CSD <sup>(a)</sup> designed for thinning aircraft coating, Mil-T-81772B) (%)	ALTERNATIVE (CSD designed for thinning dope and cellulose nitrate lacquer, Fed Std A-A-857B) (%)
MEK	30.5	12
Hexyl acetate mixed isomers	41.0	
Isobutyl acetate		31
Toluene	10.5	12
n-butyl acetate	11	
Xylenes	7.0	
Aliphatic petroleum distillates		16
n-butyl alcohol		11
Isopropyl alcohol		18
<b>TOTALS</b>	<b>100</b>	<b>100</b>

<sup>(a)</sup> CSD = Chemical Specialists & Development

As noted from the composition listings, most of the ingredients of the primer and thinner are qualitatively similar between the baseline and alternative formulations, with the differences arising in the amounts of each used. Exceptions are the use of nitromethane in the primer and the substitution of different members of the same class of compound (e.g. isobutyl instead of hexyl acetate in the thinner). Each of the differences was carried through the inventory analysis by creating new data modules where necessary or modifying others.

Inventories for each of the alternatives were constructed by modifying the baseline inventory to account for both differences in the type of ingredients and in the proportions of ingredients in the alternative primer and thinner as well as the changes in the transfer efficiency associated with the alternative spray gun. The resulting alternatives are also described below.

In general, preparing the inventory analysis for the alternative primer and thinner options consisted of a two-step process. The first step consisted of replacing certain data modules in the baseline inventory with those appropriate to the alternative formulations followed by adjustment of those modules that were qualitatively similar but proportionately different. In the case of the options involving the alternative gun, a further adjustment (decrease) was made in the overall amount of materials used to coat a functional unit area.

The only additional ingredient for which completely new data modules were required for the alternative primer was nitromethane. The MSDS for the alternative primer also listed aromatic hydrocarbons in distinction to the xylene shown for the baseline. However, because of the manner in which the refinery operations producing the aromatics occur, this distinction is not critical for the inventory. Further commentary on this issue regarding its effect on the impact assessment is

discussed below. Additional data modules required for the thinner were isobutyl acetate, n-butyl alcohol, isobutyl alcohol, and aliphatic hydrocarbons. Of these, only the isobutyl acetate and aliphatic hydrocarbons are not ingredients anywhere in the baseline system. The isobutyl acetate is produced using the same chemical operations (Oxo process) as the n-butyl acetate in the baseline primer and therefore employed the same data sources and allocation procedures. Aliphatic hydrocarbons data were derived from Battelle's refinery module. In general, data necessary for preparing the inventory of the new chemical ingredients (and their precursors back to the raw materials) were collected in much the same manner and using primarily the same sources as those described for the baseline case.

### 3.2 Environmental Impact/Hazard Assessment

An LCIA (as defined by SETAC, 1993) involves the examination of potential and actual environmental and human health effects related to the use of resources (energy and materials) and environmental releases. An LCIA is divided into the following two stages: classification and characterization. In instances where the purpose of an LCA is the assessment of the current system (i.e., a baseline analysis) a valuation phase may logically be included in the LCIA (or optionally, as was done here, may be part of interpretation). Also, a normalization stage, which compares the contributed potential impact of the system under investigation to the overall environmental problem magnitude, may be added after characterization to place the system-level results in perspective relative to the regional, national, or global perspective of the impact. In order to compare the potential environmental impacts of each alternative with the baseline conditions, an LCIA was conducted on each alternative in the same fashion as the baseline.

Classification was conducted after scoping and is the process of linking or assigning data from the LCI (Hendricks et al., 1995) to individual stressor categories within the three major stressor categories of human health, ecological health, and resource depletion. This process included creation of complex stressor/impact chains because a single pollutant can have multiple impacts, and a primary impact can result in secondary (or greater) impacts as one impact results in another along the cascading impact chain.

Characterization involved the analysis and estimation of the magnitude of impacts for each of the stressor categories by multiplying equivalency factors times the quantity of a resource or pollutant associated with a functional unit of CARC. The equivalency analysis approach functions by converting a larger number of individual inventory items within a homogeneous inventory category into a single value expressed as an amount of a reference material. The procedure generally involves multiplying the appropriate equivalency factor by the quantity of a resource or pollutant associated with a functional unit of CARC and summing over all of the items in a classification category. Finally, valuation involved assigning relative values or weights to different impacts, so they can be integrated across impact categories for use by decision makers. The valuation method used in this study is known as the Analytical Hierarchy Process (AHP). AHP is a methodology for supporting decisions based on relative preferences (perceptions of importance) of pertinent factors. Preferences were expressed pairwise in a structured manner supported by a software package known as Expert Choice (EC). For the LCImA, the characterization involved the analysis and estimation of the magnitude of the potential for each CARC system alternative to contribute to impacts in each of the stressor categories.

Five levels of analysis have been suggested by SETAC for assessing the potential human health and ecological impacts of chemical releases associated with the life cycle of a product (SETAC, 1993). These five levels of impact analysis in increasing level of complexity, effort, and site-specificity can be grouped as site-independent or site-dependent. The LCIA approach used in this report focuses on a combination of the Level 2 and Level 3, site-independent approaches discussed below:

- Level 2 - Equivalency Assessment (data aggregated according to equivalency factors for individual impacts [e.g., ozone-depletion potential or acidification potential]; assumption is that less of the chemicals with the greatest impact potential is better)
- Level 3 - Toxicity, Persistence, and Bioaccumulation Potential (data are grouped based on physical, chemical, and toxicological properties of chemicals that determine exposure and type of effect; assumption is that less of the chemicals with the greatest impact potential is better).

### **3.2.1 Classification and Stressor/Impact Chains**

The classification phase involved linking or assigning data from the LCI to individual stressor categories within the three major stressor categories of human health, ecological health, and resource depletion. Stressor/impact chains were developed by considering the energy, water, and raw material inputs to each life-cycle stage, as well as the air, water and solid waste emission outputs from each life-cycle stage. The inputs and outputs were then compared against lists of potential impacts (e.g., SETAC, 1993 and Heijungs, 1992a and 1992b), in order to develop stressor/impact chains.

### **3.2.2 Characterization**

The characterization phase involved a site-independent evaluation of the magnitude of potential impacts caused by individual stressors. For chemical stressors, this took the form of a Level 2 and/or Level 3 assessment of the physical and chemical properties of each chemical to determine the potential hazard of that chemical.

For the Level 2 evaluation, a limited subset of the chemicals identified during the LCI had already been assigned impact equivalency units in published documents. Examples of groups of chemicals that have been evaluated for impact equivalency include nutrients, global warming gases, ozone depletion gases, acidification potential chemicals, and photochemical oxidant precursors (Heijungs, 1992a; Nordic Council, 1992).

New impact equivalency units were created for some chemicals identified in the baseline or alternative LCIs, by a modification of the Level 3 Toxicity, Persistence, and Bioaccumulation Potential Approach, by adapting the hazard ranking approach described in an EPA (1994) report. This included evaluation of impacts (e.g., toxicity to humans, fish, or wildlife) other than the impacts evaluated in Level 2, although a few chemicals with multiple impacts were evaluated by both the Level 2 and 3 approaches. Some data were obtained from the EPA (1994) report, which described a method for ranking and scoring chemicals by potential human health and environmental impacts. Toxicity or persistence data for chemicals not included in the EPA (1994) chemical ranking report were obtained from electronic non-bibliographic databases available through the Medical Literature and Analysis Retrieval System (MEDLARS) or Chemical Information Systems (CIS) clearinghouses. The MEDLARS clearinghouse is available through the National Library of Medicine and contains databases such as Registry of Toxic Effects of Chemical Substances (RTECS), Hazardous Substances Databank (HSDB), and Integrated Risk Information System (IRIS). The CIS clearinghouse is available from Chemical Information Systems and contains databases such as AQUIRE and ENVIROFATE. Toxicity data are available for humans and standard laboratory animals from IRIS, RTECS, and HSDB. AQUIRE contains data on toxicity of chemicals to aquatic animals.

Evaluation of the magnitude of resource depletion impacts associated with the life-cycle of CARC started with the resource use inventory information from the LCI (Hendricks et al, 1995). Resources included in the analysis involved both flow resources, such as water, and stock resources, such as minerals, primary energy sources (e.g., gas, oil, coal), and land. These impacts were evaluated from a sustainability (time-metric standpoint), which considers the time to

exhaustion of the resource. Information on the world reserve base and production of minerals came from various U.S. Bureau of Mines publications. Information for energy sources came from the Energy Information Administration, U.S. Department of Energy.

### **3.2.3 Key Assumptions for LCIA**

Key assumptions regarding the LCIA for the baseline and each alternative include the following:

- Evaluation of the primary impact for a particular impact category is assumed to be a good indicator of the true impact of concern, which is typically further down the stressor/impact chain (e.g., an increase in the acid precipitation potential is a good indicator of the loss of aquatic biodiversity, including sport fishing).
- The generic hazard evaluation criteria discussed in Section 4 are assumed to be useful indicators of the general impact potential and incorporate some of the factors dictating the magnitude of site-specific impacts (e.g., the criteria for human, terrestrial, and aquatic toxicity include consideration of chemical toxicity and persistence). However, the exposure dose and existing environmental conditions cannot be evaluated without site-specific modeling.
- The fact that equivalency factor information was not available for a few chemicals (e.g., the toxicity or persistence of some chemicals were not in the databases searched) is assumed to have an insignificant impact on comparable impact category scores for each of the alternatives (i.e., if the information for a particular chemical is missing for the baseline, it would also be missing for the alternatives).
- The consequences of having a specific compound in the inventory for one alternative (e.g., xylene) and a class of compounds (e.g., aromatic hydrocarbons) in another was investigated using a sensitivity analysis. By evaluating the chemistry of the contributing operation and/or ingredient group, it was possible to estimate which compound or compounds were likely members of the category. Data for the selected specific compounds were then substituted and the impact equivalencies recomputed to assess the overall effect on the comparison.

## **3.3 Economic Assessment**

### **3.3.1 Methodology**

The annualized costs estimated in this analysis were restricted to internal costs (i.e., cost associated with the Army's depainting and painting operations). These costs were further classified into direct and indirect costs. Direct costs are closely associated with the depainting and painting operations and include expenses related to capital expenditures for building, equipment, renovations, etc., and operating cost such as operating labor, materials, utilities, maintenance, and waste disposal. Indirect costs are costs which are incurred but might be spread across several facilities on base and (as was done in this analysis) included in labor overhead. Examples include items such as regulatory compliance (permitting, reporting, waste handling, waste tracking, training, monitoring and analysis, emergency preparedness, and medical surveillance), waste storage, insurance, penalties and fines, and personal injury and property damage liability.

External costs, for items such as the opportunity cost of the landfill where the waste is disposed (since the site could be put to other uses, some of which might have offered more to society) have not been included in the analysis. The advantage of this approach is that information on direct and indirect internal costs were available from the Army, suppliers, and private industry. Restricting the scope in this manner allowed efforts to be focused on developing data and data analysis.

The annualized cost to depaint and paint Army vehicles was estimated using a factored estimate approach. A base case and five alternative cases (Cases 2 through 6) were evaluated (see Table 1-1). Fort Eustis was selected as the baseline site, so its plant capacity; staffing; and paint, primer, thinner, and abrasive media usage rates were used to estimate typical costs.

The factored estimate costing procedure (Peters and Timmerhaus, 1991) provides a straightforward approach to preparing cost estimates with a medium level of accuracy. Capital costs are typically accurate within  $\pm 40$  percent, and operating costs within  $\pm 30$  percent. Preparation of a more accurate estimate requires development of a detailed design, complete equipment specification, acquisition of vendor quotes, etc.

#### Capital Costs

Capital costs were estimated for a facility capable of depainting and painting Army vehicles with CARC paints. At Fort Eustis, 3,096 gallons (gal) of CARC and 32,000 pounds (lbs) of aluminum oxide were used in 1993. The plant flowsheet is shown in Figure 3-1. Capital costs were estimated for depainting, masking and equipment preparation, priming, and CARC application operations for a new facility. The primary difference in capital costs for the base case and five alternatives was use of an expensive, but more effective "Alternative Gun." The turbine-HVLP gun was capable of significantly higher spray efficiencies (90 percent versus 60 percent level assumed for the baseline gun).

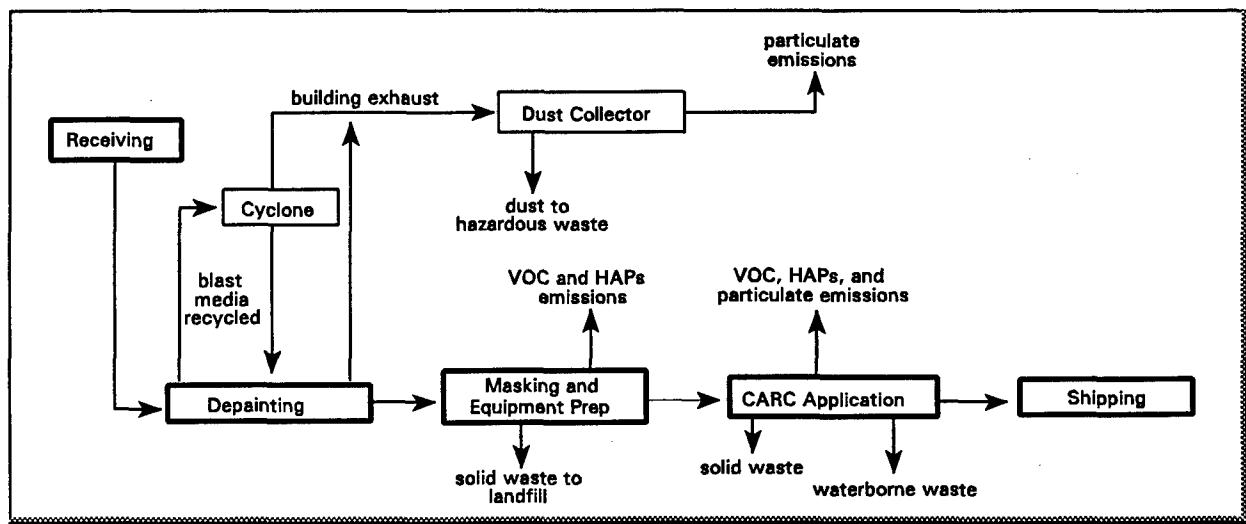


Figure 3-1. CARC application and depainting processes at Fort Eustis (from Hendricks, et al., 1995).

The factored estimate approach to estimating capital costs starts with purchased equipment. Each major item included in the design is identified, sized, and costed (using cost files, standard texts, vendor quotes, recent purchase information) to estimate the total delivered equipment costs. Then, a series of factors are applied to estimate other costs. The factors depend on the type of plant proposed, (e.g., the factors differ for a solid-solid handling plant versus a solid-liquid, or liquid-liquid facility). The factors for solid-solid processing were felt most appropriate for CARC depainting

and painting. The factors were obtained from a standard engineering-economics text that has been found to provide reasonable estimates of capital costs (Peters and Timmerhaus, 1991).

#### Operating Costs

Operating costs are composed of the annual costs to operate the depainting and painting operations. They include raw materials, utilities, labor, supplies, maintenance, plant overhead, waste disposal, insurance, and regulatory compliance charges. At Fort Eustis, a team of five operates the depainting facility and a team of eight mans the painting facility. In 1993, 32,000 lbs of aluminum oxide abrasive and 3,096 gal of CARC were used to depaint and paint approximately 480 Army vehicles (Hendricks, et al., 1995; Cavender, et al., 1994).

To estimate operating costs, the quantity of raw materials, utilities, and labor used were estimated based on the experience at Fort Eustis. The effect of the alternative cases on these usage rates were also estimated. Appropriate factors were applied to convert the usage rates to annual costs (i.e., the gallons of CARC used per years were multiplied by the CARC purchase price). Other charges, such as for maintenance, plant overhead, etc, were estimated using factors (e.g., maintenance charges were estimated as a function of the estimated fixed capital investment). These factors were obtained from the same engineering-economics text (Peters and Timmerhaus, 1991).

#### Annualized Cost

Annualized costs equal the annual operating cost plus amortization of the fixed capital investment (FCI). There are many procedures employed to amortize capital costs. The factor used is usually dependent on the interest rate and time period selected. For this estimate, an annual charge was applied equivalent to making 12 monthly "mortgage" payments, at 6 percent interest over a loan life of 11 years to repay the base case FCI or the alternatives FCIs. The total annualized cost is then computed as:

$$\text{Operating Cost, } \$/\text{yr} + \text{Amortization, } \$/\text{yr} = \text{Annualized cost, } \$/\text{yr}$$

This cost was also divided by the annual quantity of CARC painted surface to compute costs on a \$/1000 ft<sup>2</sup> basis. The annual surface coated (619,000 ft<sup>2</sup>) was estimated from the 1993 Fort Eustis CARC paint consumption level of 3,096 gallons and a calculated CARC usage rate of 5 gal/1,000 ft<sup>2</sup> (200 ft<sup>2</sup>/gal).

#### 3.3.2 *Evaluated Parameters*

##### Capital Costs

###### *Depainting*

A schematic of the depainting booth at Fort Eustis is presented in Figure 3-2. The depainting building is approximately 24 feet by 36 feet. Operations include receiving the 16-mesh aluminum oxide grit, feeding it to holding pots, and high-pressure air blasting through a nozzle to remove old paint and/or rust from steel substrates. Two induced draft fans are employed to transport paint chips and fine aluminum oxide dust suspended in the air to a series of dust collectors for dust removal. After the initial blasting, most of the media used is still large enough for reuse. This media and paint chips, flakes, masking tape, small pieces of debris, etc. are manually swept into floor grates. Screw conveyors in the grates move the media to a bucket elevator which discharges into a collection hopper. Media is discharged from the hopper and passed through an air stream. The lighter materials are picked up by the air and carried to a cyclone separator to remove the waste materials. The larger, heavier material drops to a storage hopper for reuse.

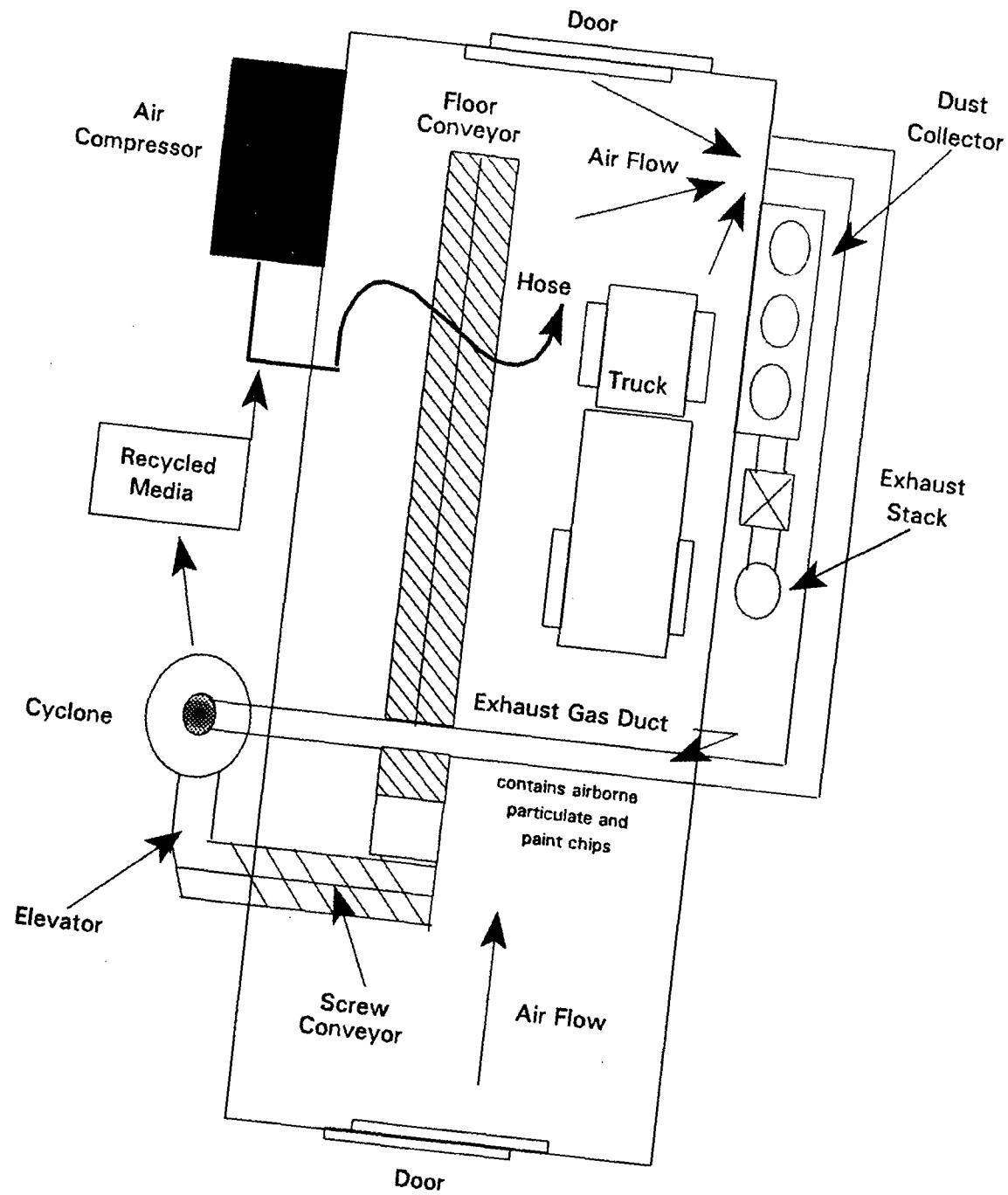


Figure 3-2. Fort Eustis depainting building (Cavender, et al., 1995).

The estimated purchased equipment costs for the depainting totaled \$75,000 for the screw conveyor, cyclone, air wash system, platform, building ventilation blower, air compressor, depainting hoses, nozzles, etc., dust collector, and duct work. The building was estimated separately based on floor space (30 feet by 50 feet) and building type at \$65,000. To these delivered purchased costs, factors described earlier were applied to estimate the direct cost, indirect cost, and fixed capital investment.

#### *Painting*

After depainting, the vehicles are hand-wiped with thinner to remove grease and dirt. Once cleaned, the vehicles are hand-masked with tape and paper before being moved into one of two downdraft painting booths.

In the base case, vehicles are first painted with a two-part epoxy primer (MIL-P-53022). The primer is composed of 80 percent part A and 20 percent part B, by volume. The primer is thinned with the base case thinner MIL-T-81772B prior to application. The primer is applied using the base case spray applicator a HVLP gun. The primed surface is allowed to dry for 2 hours before application of CARC. Alternative primers, thinners, and spray guns were also evaluated.

A single component CARC (MIL-C-53039A), Hentzen 08605 GUZ-GD, 1-part urethane, is applied using the base case applicator a HVLP gun. Prior to application the CARC is mixed with thinner to achieve the desired viscosity and drying time. After painting, the guns and hoses are cleaned with thinner at the end of each shift. The waste thinner is collected, allowed to settle, and reused. The collected sludge is disposed as hazardous waste. An alternative gun was also evaluated. It was assumed that the same type of gun was used for both primer and CARC application.

The purchased equipment costs for the painting operation totaled \$35,000 for the building ventilation blower, duct work, water-wall collection system, and the dust collectors. The base case gun (HVLP) capital costs were estimated at two guns at \$250 each plus \$10,000 for a 30-horsepower (HP) air compressor and associated painting equipment. The cost for the alternative gun, a turbine HVLP gun, was \$20,000 for four guns and all associated equipment. The difference in gun cost was the only significant capital cost difference between the baseline case and the five alternative cases. The building (24 feet by 36 feet) was estimated separately at \$37,000. The factors noted before were applied to estimate FCI. The combined estimated capital cost was \$547,000 for the depainting and painting facilities using the base case HVLP spray applicator, and \$581,000 for the depainting and painting facilities using the alternative gun.

#### **Operating Costs**

Numerous assumptions were required to estimate operating costs. Unit costs for raw materials, utilities, labor, and waste disposal are provided below. The raw materials required and their unit costs are provided in Table 3-4. The only utility used in significant quantities was electricity. The unit cost was assumed to be \$0.06/kilowatt (kW-hr). A labor rate of \$25/man-hr was assumed. Supervisory labor and plant overhead charges were estimated as separate items using factors presented earlier.

Disposal costs for waste paint and primer, thinner sludge, etc. were estimated at \$500/drum or \$10/gal. Disposal charges for waste painting materials, tape, paper, filters, etc. were estimated at 100 percent of paint and primer waste disposal charges. Spent blasting media disposal costs were estimated at \$0.58/lb (Mayer, 1994).

Table 3-4. Raw Material Unit Costs

Item	Description	Price	Reference
Topcoat	MIL-C-53039A, 1-part urethane	\$36.00/gal	Miller, 1994
Base case Primer	MIL-P-53022, 2-part epoxy	\$17.00/gal	Miller, 1994
Alternative Primer	MIL-P-53030, Deft 2-part epoxy	\$20.33/gal	Taylor, 1995
Base case Thinner	MIL-T81772B	\$15.00/gal	Taylor, 1995
Alternative Thinner	Fed. Std. A-A-857B	\$15.00/gal	Taylor, 1995
Abrasive	16-mesh aluminum oxide	\$0.25/lb	Skillen, 1994

#### Process Related Assumptions

Assumptions on work load, coating thickness, density, percent solids, coating efficiency, waste, dilution, coverage rate, work period, depainting rate and abrasive usage were estimated. These assumptions and information sources are presented in Table 3-5. The required materials for 619,000 ft<sup>2</sup> painted (primer and topcoat) per year, based on 190 painting days/year at Ft. Eustis were:

- 3,096 gal CARC/yr
- 1,827 gal primer/yr
- 1,627 gal thinner/yr
- 32,970 lb aluminum oxide abrasive/yr, and
- 73,972 lb spent abrasive/yr.

Since power and labor were anticipated to be significant cost factors, they were estimated in detail. Total power requirements were summarized at 94 HP (or HP equivalent) for the following operations:

- Painting building ventilation
- Painting building lights
- Painting building heating/air conditioning
- Air compressor for painting
- Air compressor for priming
- Depainting building ventilation
- Depainting building lights
- Depainting building heating/air conditioning
- Depainting pneumatic conveying
- Depainting air cleaner blower, and
- Air compressor for depainting blast nozzles.

Use of the alternative gun lowered total power usage to 72 HP. The difference results from the need to use a 30-HP air compressor for the HVLP spray application gun versus 7.5-HP for the alternative gun (turbine HVLP gun) (Bunnell, personal communication, 1995).

**Table 3-5. Process Assumptions**

Item	Description	Value	Reference
Workload	Painting 1000 ft <sup>2</sup> / day	3.26 1000-ft <sup>2</sup> units/day	Estimated based on LCI <sup>(a)</sup> 3,096 gal CARC used/yr
Topcoat with HVLP gun	Usage, gal/1000 ft <sup>2</sup>	5.00 gal/1000 ft <sup>2</sup>	Calculated
Topcoat with alternative gun	Usage, gal/1000 ft <sup>2</sup>	3.66 gal/1000 ft <sup>2</sup>	Calculated
Base case primer with HVLP gun	Usage, gal/1000 ft <sup>2</sup>	2.50 gal/1000 ft <sup>2</sup>	Calculated
Alternative primer with HVLP gun	Usage, gal/1000 ft <sup>2</sup>	2.50 gal/1000 ft <sup>2</sup>	Calculated
Base case primer with alternative gun	Usage, gal/1000 ft <sup>2</sup>	1.805 gal/ 1000 ft <sup>2</sup>	Calculated
Alternative primer with alternative gun	Usage, gal/1000 ft <sup>2</sup>	1.805 gal/ 1000 ft <sup>2</sup>	Calculated
Thinner with topcoat - HVLP gun	Usage, gal/1000 ft <sup>2</sup>	1.625 gal/ 1000 ft <sup>2</sup>	Calculated
Thinner with topcoat and base case or alternative primer - alternative gun	Usage, gal/1000 ft <sup>2</sup>	1.625 gal/ 1000 ft <sup>2</sup>	Calculated
HVLP gun with topcoat	Coverage, ft <sup>2</sup> topcoat/min	2.0 ft <sup>2</sup> /min	(K. Taylor, Battelle, personal experience)
Alternative gun with topcoat	Coverage, ft <sup>2</sup> topcoat/min	3.0 ft <sup>2</sup> /min	Calculated
HVLP gun with primer	Coverage, ft <sup>2</sup> primer/min	2.0 ft <sup>2</sup> /min	(K. Taylor, Battelle, personal experience)
Alternative gun - base or alt. primer	Coverage, ft <sup>2</sup> primer/min	3.0 ft <sup>2</sup> /min	Calculated
Work factor, minutes painting day	Painting min/day	3,260 min/day	Calculated
Work factor, days painting/year	Painting day/yr	190.0 days/yr	Calculated
HVLP gun for topcoat	Guns required to paint 1000 ft <sup>2</sup> topcoat/day	0.2/1000 ft <sup>2</sup> /day	Calculated
Alternative gun for topcoat	Guns required to paint 1000 ft <sup>2</sup> topcoat/day	0.13/1000 ft <sup>2</sup> /day	Calculated
HVLP gun - base or alternative primer	Guns required to apply primer 1000 ft <sup>2</sup> /day	0.2/1000 ft <sup>2</sup> /day	Calculated
Alternative gun for base case primer	Guns required to apply primer 1000 ft <sup>2</sup> /day	0.13/1000 ft <sup>2</sup> /day	Calculated
Alternative gun for alternative primer	Guns required to apply primer 1000 ft <sup>2</sup> /day	0.10/1000 ft <sup>2</sup> /day	Calculated
Depainting	Depainting rate, ft <sup>2</sup> /min	1.1 ft <sup>2</sup> /min	(Skillen, 1994, p 26)
Existing units average paint thickness	Thickness, mil paint removed	6.9 mil	Calculated
Density of old paint	Density, lb/gal	77.0 lb/ft <sup>3</sup>	Calculated
Grit usage	Required grit, lb/lb paint removed	0.76 lb/lb paint removed	Calculated from LCI <sup>(b)</sup>

(a) Hendricks et al. (1995)

(b) Cavender et al. (1994)

Base case labor requirements were estimated at 110 man-hr/day for the 3,260 ft<sup>2</sup> of topcoat applied each working day at Fort Eustis. The rates by application were:

- Depainting (pre-strip preparation, depainting, post strip completion inspection and clean-up): 41 hours
- Primer (thin primer with thinner, prepriming preparation, apply primer, post primer application inspection and cleaning): 44 hours
- Topcoat (thin topcoat with thinner, apply top coat using HVLP gun, post topcoat application inspection and clean-up): 24 hours

This was reduced to an estimated 96 hours when the more efficient alternative gun was employed. Depainting time naturally stayed the same (41 hours), but preparation and priming dropped to 38 hours and topcoat application, inspection, and cleanup dropped to 17 hours.

### **3.4 Performance Assessment**

The major technology driver for advances in coatings and in application equipment is the reduction of emissions of volatile organic compounds (VOCs). Coatings are currently being formulated that either reduce the level of solvent in the coating (high solids), eliminate the use of solvents (powder coating, 100% reactive-UV curable) or use water as a solvent or co-solvent (waterborne, waterthinned). The application equipment manufacturers are working with coatings manufacturers to allow the use of these reduced VOC coatings. High-solids systems require increased nozzle pressures to provide atomization of the high viscosity materials. Powders coatings require the use of electrostatic equipment which electrically charges the powder to provide an attractive force between the powder and the substrate. Waterborne coatings require the use of stainless systems to prevent corrosion.

At this time there is only one military specification (Mil-C-53039) approved for use as a CARC topcoat for the exterior of vehicles. This is a one-component, moisture-cured, solvent-based polyurethane. High-solids, water-based, and 100% reactive systems are currently being investigated. However, none of these systems are expected to receive approval in the short term according to personnel at Fort Belvoir (U. S. Army Coatings Research Facility) (Duncan, personal communication, 1995). Primers are limited to two military specifications (Mil-P-53022 and Mil-P-53030). Both system are two component epoxy-amine systems. Mil-P-53030 is a water-thinnable formulation.

Other formulations may exist that provide all of the necessary performance characteristics obtained from the currently used systems. However, without available supporting data, these systems can not be explored within the scope of this program.

#### **3.4.1 Application Equipment**

Electrostatic guns and HVLP guns are the two most commonly used market advances. Electrostatic guns charge atomized paint particles and use the attractive force of a grounded target to attract and hold the coating particle. This reduces both the amount of bounceback and overspray. Bounceback is due to high momentum particles not having enough attractive force upon impacting a target to inhibit the particle from bouncing off the target. Overspray is due to the turbulence involved in forcing a coating through a gun path toward a target. Both bounceback and overspray are reduced because the attractive force of the target allows for reduced forward pressure from the guns. The HVLP guns reduce the pressure or force on the particles, which reduces the amount of bounceback. However, HVLP guns often require a conversion zone which changes high pressure air into large volumes of low pressure which influences the amount of turbulence and the amount of overspray.

Transfer efficiency is the defining value of the ability of application equipment to minimize overspray and bounceback. Transfer efficiency is measured as the amount of coating that is applied to the surface over the total amount sprayed. Higher transfer efficiencies result in use of less material and thus less VOC release.

While manufacturers strive for increases in transfer efficiencies, the equipment must also continue to impart a quality coating on the target surface. The surface characteristics of the applied film are directly related to the atomization, and velocity of the applied coating particles. The effect of varying levels of atomization and velocities on proper film formation are reviewed in available literature, but will not be discussed in this review. The equipment must also allow for coating at a range of film thicknesses and coverage areas similar to that available from conventional application equipment.

### **3.4.2 Primers**

Primers serve two basic functions which are corrosion protection and as tie layers which aid adhesion of topcoats. The area of corrosion is complex and will not be covered in detail in this discussion, as much literature is available on the subject (Wicks, 1987). However, in general the most common driver is electrochemical corrosion. Electrochemical corrosion is in turn a function of, but not limited to, the following: the type of metals involved, the environmental conditions present including humidity and salt levels, and mechanical stress found in the metal structure.

Adhesion is affected by both the materials used and the condition of the substrate. Most primers considered for use under CARC topcoats on steel consist of two-component, amine-cured, epoxy systems. The amine component is used because of strong hydrogen bonding that occurs with oxides formed on the steel surface. Epoxy-amine systems have been traditionally viewed as having excellent adhesion and hardness. However, they do not have the required environmental and chemical exposure resistance needed to be used as an external CARC topcoat. Therefore, these primers must also be reviewed in terms of the adhesive strength between the primer and a more environmentally durable polyurethane topcoat.

The condition of the substrate is important, because small levels of contaminants such as oils and greases can dramatically reduce the bonding of the primer. Systems with the greatest adhesion are often less dependent upon absolute cleanliness of the substrate and are therefore less susceptible to oversights in surface cleaning.

An additional performance related factor that can be included toward the selection of a primer is the ease of use of the primers. Two component systems require the blending of a base and a catalyst which initiates immediate crosslinking, which in turn results in increases in viscosity. Therefore, the systems must be applied before the reaction of the two components increases the viscosity beyond application limits. This rate of reaction is reported as the cure rate and is often more simply expressed in terms of a system's "pot life". "Pot life" is generally defined as the amount of time elapsed after initial mixing before the viscosity of the system doubles. The ease of cleanup of the primers can also be considered. Systems that require extensive use of solvents to clean gun lines require more effort than those that can be cleaned using water.

### **3.4.3 Thinners**

There are three major factors associated with the selection of a solvent or thinner. The first is the solubility of the solute (i.e., the paint and/or resin) by the solvent. This factor is based on the compatibility of the solute and the solvent, which is demonstrated as the ability of the solute and the solvent to form a homogenous solution and it is often referred to in terms of the solubility parameter. The second factor is the viscosity reduction introduced by the addition of the solvent. The first two factors are related as the solvency of the thinner. Solvency is generally dominated by

the viscosity of the solvent when low concentrations of resin are present. When higher concentrations of resin are introduced, then the solubility factor dominates the overall viscosity. However, the amount of thinner required to thin the paint and or primer are more commonly considered by end users than the individual contributions of solvency. The final factor is the evaporation rate of the resin and its affect on film formation. "If solvent evaporation is too fast, the film will not level nor wet the substrate well enough for good adhesion. If the solvent evaporation is too slow, the film will sag and perhaps become too thin. If solvent composition changes during evaporation, precipitation of the resin can occur, and the film will have no integrity" (Ellis, 1986). It is the effect of the evaporation rate on the film forming characteristics of the coating that are of primary concern and of which the most informative data can be obtained.

One additional factor that can also be considered is the level of purity of the thinners. Thinners with significant levels of contaminates such as water or solid particulates can affect the film characteristics of the coating.

#### **3.4.4 Application Equipment Evaluation Parameters**

Surface quality and transfer efficiency were selected as the two evaluation parameters. The ability of the application equipment to provide sufficient atomization and desired thickness levels and coverage areas were not chosen as evaluation parameters due to information provided by equipment manufacturers stating that these issues could be ignored assuming the proper selection of nozzles and tips.

##### **Surface Quality**

The ability of the application equipment to effectively apply CARC was ranked according to the surface quality of the applied coating. An acceptable finish is one with no visible application induced surface blemishes (e.g., orange peel, blistering). Data were obtained from published literature. Results were ranked in terms of acceptable and not acceptable, as follows:

- 2: Acceptable: No visible application induced surface blemishes
- 1: Not Acceptable: Noticeable surface blemishes requiring significant reformulation efforts such as addition of thinners, or surfactants.

##### **Transfer Efficiency**

Transfer efficiency (TE) was rated by definition as the percentage of paint applied to the target divided by the total paint sprayed. Data were obtained from published literature and communications with users. Results were reported from 0-100 percent, and were ranked as follows:

- 4: TE for alternative > 20% + TE for baseline
- 3: TE for alternative > (10% to 20%) + TE for baseline
- 2: TE for alternative > (0% to 10%) + TE for baseline
- 1: TE for alternative < TE for baseline

The evaluation parameters Surface Quality and TE are weighted 2-1, respectively.

#### **3.4.5 Primer Evaluation Parameters**

The two major issues of primers are corrosion inhibition and adhesion. Cure rate was also identified as a possible selection parameter in the methodology section. Unfortunately, a lack of data for primers is available in terms of corrosion inhibition. However, as stated in the assumptions, the reviewed primers have all met military specification approval and thus are assumed to provide sufficient corrosion inhibition.

Adhesion is reviewed in terms of the level of cleaning of the substrate required for acceptable adhesion. Adhesion of the primer and the topcoat can also be affected by changes in environmental conditions and will thus be reviewed separately. Cure rate and ease of cleanup will be reviewed in respect to the impact on the painting schedule and the level of effort required.

#### Effect of Temperature and Humidity

Adhesion of the primer to the substrate and also the adhesion of the topcoat to the primer can be affected by differences in environmental conditions. Data were obtained from personal interviews with users. The level of impact of changes in temperature and humidity were reviewed, and the effect of each criterion was ranked according to the following scale:

##### Changes in humidity and temperature have:

- 4: No observable impact
- 3: Minimal impact not seen as having practical significance
- 2: Noticeable impact
- 1: Critical impact

#### Cure Rate

The rate of viscosity increase can induce limitations on the amount of primer that can be mixed at a given time if the cure rate is too fast. This results in an increase in time spent preparing the primer and also in maintaining flow in the application lines. Cure rates that are too slow can result in increased down time due to required waiting periods between coats.

The impact of the primer cure rate was reviewed. Data were obtained from personal interviews with users. Results were reported in terms of the following scale:

- 4: Cure rate had no effect on the painting schedule
- 3: Cure rate had minimal effect on the painting schedule
- 2: Cure rate had dramatic effect on the painting schedule
- 1: Cure rate had unacceptable effect on the painting schedule

#### Surface Pretreatment Requirements

The level of cleaning of the surface to be coated with primer was reviewed. Data were obtained from personal interviews with users. Results were reported in terms of the following scale:

- 4: no cleaning was required
- 3: minimal cleaning with dry rag required
- 2: minimal cleaning with solvent rag required
- 1: repeated cleaning with solvent rag required

#### Ease of Cleanup of the Primer

Primers were ranked in terms of ease of cleanup. Those that are easily thinned increase the ease of cleanup, which results in a decrease in time spent and in the use of solvents. Data were obtained from personal interviews with users. Results were reported in terms of the following scale:

- 4: no effort required for cleanup
- 3: minimal effort required for cleanup
- 2: moderate effort required for cleanup
- 1: extreme effort required for cleanup

The evaluation parameters Effect of Temperature and Humidity, Cure Rate, Surface Pretreatment Requirements, and Ease of Cleanup of the Primer Changes are weighted 3-1-1-1, respectively.

### **3.4.6 Thinner Evaluation Parameters**

#### **Thinning Ratio or Thinner Effectiveness**

Thinners were evaluated based on the percentage of thinner needed to dilute CARC to within sprayable viscosity limits. Data were obtained from personal interviews with users. Results were ranked as follows:

4: Thinning ratio for alternative	>	(50%) reduction
3: Thinning ratio for alternative	>	(25% to 50%) reduction
2: Thinning ratio for alternative	≥	(0% to 25%) reduction or no change
1: Thinning ratio for alternative	>	(0% to 25%) increase

Thus, the score for the baseline is 2.

#### **Film Characteristics**

Thinners were also ranked according to the ability of the thinner to provide an acceptable finish. Thinners that evaporate too slowly or too quickly can cause undesirable surface defects such as sagging or running and blushing, popping, and orange peel. Data were obtained from personal interviews with users. Results were reported in terms of level of surface flaws as follows:

4: No noticeable blemishes
3: Minimal blemishes not believed significant
2: Noticeable blemishes bordering acceptability
1: Unacceptable level of blemishes

The evaluation parameters Thinning Ratio or Thinner Effectiveness and Film Characteristics are weighted equally.

### **3.5 Valuation Procedure**

Finally, as noted above, valuation involves assigning relative values or weights to different impacts, so they can be integrated across impact categories for use by decision makers. It should be recognized that this is largely a subjective process, albeit one that is informed by knowledge of the nature of the issues involved. The valuation method used in this study is known as the Analytical Hierarchy Process (AHP). AHP is a recognized methodology for supporting decisions based on relative preferences (importance) of pertinent factors (Saaty, 1990).

The AHP process involves a structured description of the hierarchical relationships among the problem elements, beginning with an overall goal statement and working down the branches of the tree through the major and minor decision criteria. Once the decision tree is defined, the actual assignment of the weight factors occurs. In this study, the assignment of weights was done as a group exercise. The advantages of the AHP method include its structured nature and the fact that the valuation process does not deal with the entire set of criteria at one time, an effort that would be overwhelming. Rather, preferences are expressed by the team in a pair-wise manner supported by a software package known as Expert Choice™ (EC). The four member team was asked to reach a consensus on the weight factors prior to their being entered into the model. Although divergences of preference could in principle be retained as separate sets of criteria, it was felt that for this application, a single internally consistent process would lead to clearer understanding of how the implementation of the results should proceed.

One of the key assumptions in applying the AHP method is that the environmental, cost, and performance perspectives of the four Battelle staff conducting the AHP to determine the assignment of weighting values for comparison of different impact criteria are assumed to be a reasonably good cross section of the views held by similar stakeholders in the decision process. Because the four staff included one cost engineer, one paints/coatings specialist, a civil engineer and an ecologist, we believe that the mix (and the resulting weights) are reasonable. Facility/production engineers and other "non-environmental" staff within the Army, however, may have derived somewhat different weight values.

## **4.0 Description and Screening of Improvement Options**

### **4.1 Alternatives Identified/Selected**

The scoping process conducted for the baseline and alternatives was designed to identify candidate improvement options that could be evaluated and implemented with a moderate amount of effort and within a reasonable timeframe. It was therefore determined that options requiring large changes in technology or overcoming major institutional barriers, for example, a modification to the MIL-SPEC, a significant change in Army purchasing practices, or a major capital acquisition, would not be included in the suite of candidate systems even though these might, in the long run, be very much better environmentally than those considered. The five alternatives selected (see Table 1-1) represent a mix of evolutionary, directional changes in paints and technology that individually and in combination represent an incremental improvement potential in the areas most directly affecting the environmental profile as determined by the baseline analysis.

Three of the alternatives consider the use of an alternative primer consisting of a water-thinned rather than a solvent-thinned formulation. Although primarily expected to reduce VOC releases during the painting operation, this substitution also offers potential changes in the entire life-cycle of the primer manufacture, use, and disposal. This alternative material is also combined with an alternative thinner in one scenario and with an alternative spray gun in another. The alternative thinner would be anticipated to offer further directional improvements in chemical emissions and the alternative gun application of both more paint on the surface as well as greater labor efficiency. Finally, the alternative thinner and gun systems can be used independently of the alternative primer, although any additive benefits (or costs) would not occur. The following section presents and discusses the factors comprising the improvement assessment process in each of the three target assessment areas.

### **4.2 Environmental Impact/Hazard Classification**

Based on a scoping process using the LCI data that was revised and updated for the baseline and alternatives, and a review of stressor/impact chains for all resources used, and environmental releases from, the entire CARC life cycle, nine major environmental impact categories were selected for the streamlined LCIA described in this report. These nine impact categories include:

- photochemical oxidant creation potential (POCP; also called smog formation potential),
- ozone depletion potential (ODP; stratospheric ozone depletion),
- acidification potential (AP; acid rain/fog),
- global warming potential (GWP; also called greenhouse effect potential),
- human health inhalation toxicity (acute inhalation toxicity),
- terrestrial toxicity (acute oral wildlife toxicity),
- aquatic toxicity (acute fish toxicity),
- land use (for solid waste disposal), and
- natural resource depletion (including fossil fuels and minerals).

Stressor/impact networks for these nine major impacts are shown in Table 4-1. This table shows the secondary, tertiary, and quaternary impacts that can result from the primary impact used

in the impact equivalency calculations. Thus, impacts to human health can result from several of these major impact categories (e.g., inhalation toxicity, smog formation, and ozone depletion). The potential for both positive and negative impacts were viewed from a global perspective. For example, global warming may increase food production in some areas (e.g., cold climates) and decrease food production in other areas (e.g., warm climates). Where the global net difference in positive and negative change for a single impact criterion was not clear, both types of impacts were listed for that criterion. Although other minor impacts are associated with the CARC life cycle, these major impact categories were expected to show significant differences between the alternatives to the base case selected for this LCIa. Many of the impacts selected for analysis were also identified in a document by Inform, Inc. titled "Stirring Up Innovation: Environmental Improvements in Paints and Adhesives" (Young et al., 1994). The Inform study was conducted with the cooperation of major paint manufacturing companies.

Table 4-1. Stressor/Impact Networks for Impacts of Primary Concern in CARC Life Cycle

Stressors	Primary Impact	Secondary Impact	Tertiary Impact	Quaternary Impact
CO <sub>2</sub> Carbon tetrachloride Trichloroethane	Global warming	Polar melt	Flooding/land loss	
		Soil moisture loss	Lower food production	
		Longer season	More food production	
		Forest loss/change	Decreases biodiversity and forest production	
		Change in wind and ocean patterns		
SO <sub>x</sub> NO <sub>x</sub> Ammonia Hydrochloric acid	Acid rain/fog	Building corrosion	Loss of infrastructure, loss of heritage resources	
		Water quality (acidification)	Decreased aquatic biota reproduction and populations	Decreased biodiversity, decreased recreational and commercial fishing, decrease in water birds
		Vegetation effects	Agricultural and terrestrial productivity effects	
		Soil effects	Vegetation effects	Agricultural and terrestrial productivity effects
VOCs Acetaldehyde Toluene Benzene n-Butane n-Octane n-Butyl Acetate Chloroform etc.	Ground-level ozone (smog) creation by photochemical oxidants	Decreased visibility		
		Eye irritation		
		Respiratory tract problems and lung irritation	Morbidity	
		Vegetation damage	Decreased agricultural / terrestrial productivity	

**Table 4-1. Stressor/Impact Networks for Impacts of Primary Concern in CARC Life Cycle (continued)**

Stressors	Primary Impact	Secondary Impact	Tertiary Impact	Quaternary Impact
Ammonia Fluorine Xylene Chlorine Vinyl Chloride Phenol CO, etc.	Human health and inhalation toxicity	Morbidity or mortality		
<u>Heavy Metals</u> (Arsenic, cadmium, chromium, mercury) Ammonia Benzene Hydrochloric acid Phenol Sulfuric acid, etc.	Aquatic biota toxicity	Decreased aquatic plant and insect production and biodiversity	Decreased commercial or recreational fishing	
Coal use Iron ore use Magnesium ore use Petroleum use Thallium use Titanium use Water use Zinc use, etc.	Resource depletion	Resources unavailable for future generations		
<u>Heavy Metals</u> (Arsenic, cadmium, chromium, lead) Formaldehyde Sulfuric acid Hydrogen cyanide	Terrestrial animal toxicity	Decreased production and biodiversity	Decreased wildlife for hunting or viewing	
Carbon tetrachloride Trichloroethane	Stratospheric ozone depletion	Increased ultraviolet radiation penetration of Earth's atmosphere	Increased incidence of human skin cancer and ecosystem effects	
Bottom ash FGD solids Fly ash Hazardous waste Plutonium Slag Solid waste Uranium	Land use for disposal	Loss of terrestrial habitat for wildlife  Decreased landfill space		

In order to combine data on individual chemicals or resources within an impact category, it was necessary to select existing, or develop new, impact equivalency factors as recommended by SETAC (1993) for a Level 2/3 LCIA. The equivalency factors for each impact category are listed in Table 4-2. The equivalency factors for POCP, AP, GWP, and ODP were taken from Heijungs et al. (1992b); the derivation of these factors is described in a companion document (Heijungs et al., 1992a). The general approach for calculation of equivalency factors for the three toxicity impact criteria was modified from an EPA (1994) document prepared by the University of Tennessee. Details for determining the equivalency factors for the three toxicity criteria, land use, and resource depletion are discussed below.

**Table 4.2. Chemical Equivalency Factors for Major Impact Categories Associated with CARC LCA**

CHEMICAL NAME	POCP*	ODP	AP**	GWP***	HH INHALATION TOXICITY	TERRESTRIAL TOXICITY	AQUATIC TOXICITY	LAND USE	RESOURCE DEPLETION
ACETALDEHYDE	0.527				7.44	3.255			
ACETONITRILE					0	0.61	0		
ALDEHYDES	0.443				NA				
ALIPHATIC PETROLEUM DISTILATES					15.6	0	0		
ALUMINUM					5.7	9.03	21.85		
AMMONIA		1.88			NA				
AROMATIC HYDROCARBONS (C8-C10)	0.761								
AROMATIC SOLVENT	0.761								
ARSENIC									
BAUXITE					31.73	18.75			
BENZENE	0.189				NA	0	14.07		
BORON					0	0			
BOTTOM ASH					17.5			2	
BUTANE (n-)	0.41				NA				
BUTANE (iso-)	0.315				8.49	0			
BUTYL ACETATE (n-)	0.323				0.95	6.18	0		
BUTYL ALCOHOL (BUTANOL)	0.196				12.29	7.59			
BUTYL CELLOSOLVE					NA	1.61	NA		
BUTYLENE OXIDE, 1,2-					2.25	21.03	36.25		
CADMIUM					1300	7.06	1.71	1.2	
CARBON TETRACHLORIDE	1.08								
CHLORIDE									
CHLORINE					22.05	0	22.5	NA	
CHLOROFORM	0.021				2.57	6.16	9.75		
CHROME OXIDE									
CHROMIUM, TRIVALENT					0	19.29	16.63		
CO					4.47				
COAL					1	NA			
COBALT COMPOUNDS								3	
COBALT OXIDE						20.96	31.75		
COPPER COMPOUNDS					0	12	30		
CUMENE					1.35	2.71			
CYCLOPARAFFINS, C-7					NA				
CYCLOPARAFFINS, C-8					NA				
DICHLORODIFLUOROMETHANE (CFC-12)	1				1	1.33	NA		
DIETHYLENETRIAMINE					7100	0	5.27		
ETHANE						NA			
ETHYL BENZENE	0.082					3.19			
ETHYL CHLORIDE	0.593					0	0		
ETHYLENE	1					0	0		
ETHYLENE DICHLORIDE						7.32	4.89		
FGD SOLIDS									
FLY ASH								2	
FLUORINE								2	
FORMALDEHYDE						14.64			
HAZARDOUS WASTE						15.6	12.6		
HEAVY AROMATIC								2	
HEPTANE (n-)	0.529					0	NA	9.5	

**Table 4.2. Chemical Equivalency Factors for Major Impact Categories Associated with CARC LCA (continued)**

CHEMICAL NAME	POCP*	ODP	AP**	GWP***	HH INHALATION TOXICITY	TERRESTRIAL TOXICITY	AQUATIC TOXICITY	LAND USE	RESOURCE DEPLETION
HEXYL ACETATE					NA	0	0		
HEXANE (n-)	0.421				0	0	0		
HYDROCHLORIC ACID			0.88		14.82	5.74	13.86		
HYDROGEN CYANIDE					30	30			
IRON					0	0	25		
IRON ORE								3	
ISOBUTYL ACETATE	0.332				1.86	1.86			
ISOBUTYRALDEHYDE					0	0.95			
ISOPROPYL ALCOHOL						0			
KEROSENE					NA	NA			
LEAD						5.75	25		
LIMESTONE							1		
MAGNESIUM ORE							1		
MAGNETITE								1	
MANGANESE ACETATE									
MERCURY							37.5		
METHANE	0.007				NA				
METHANOL	0.123				0	0	0		
METHOXYPROPANOL ACETATE									
METHYL ETHYL KETONE	0.473				1.4	1.86			
METHYL ISOAMYL KETONE	0.326				4	2.05	10.2		
METHYL ISOBUTYL KETONE	0.326				2.33	2.79			
METHYL PROPYL KETONE	0.326				NA	4.57			
NAPHTHA, NM&P					NA				
NAPHTHALENE					26.45	3.17	19.57		
NATURAL GAS								4	
NOX					0.7	NA			
NITRIC ACID						26.4	10.2	15.6	
NITROETHANE						NA			
NITROPROPANE, 2-						14.4	8.4	23.4	
OCTANE (n-)	0.493				0	NA			
OIL & GREASE									
ORGANIC ACIDS						NA	NA		
PENTANE (n-)	0.408					13.34			
PETROLEUM (CRUDE OIL)							NA		
PHENOL							NA		
PHOSGENE						22.33	7.6	11.4	
PHOSPHATE ROCK								4	
PHOSPHORIC ACID									
PLUTONIUM (FISSILE & NONFISSILE)						30	5.4	11.4	
PM						NA			
PROpane						NA			
PROPYL ACETATE						NA			
PROPYLENE						NA	0.87		
SLAG								2	
SODA ASH								1	
SODIUM CHLORIDE							NA		1

**Table 4-2. Chemical Equivalency Factors for Major Impact Categories Associated with CARC LCA (continued)**

CHEMICAL NAME	POCP*	ODP	AP**	GWP***	HH INHALATION TOXICITY	TERRESTRIAL TOXICITY	AQUATIC TOXICITY	LAND USE	RESOURCE DEPLETION
SOLID WASTE									
SOX								1.5	
SILICA									1
SULFIDE									
SULFURIC ACID									
SULFUR DIOXIDE									
THALLIUM									
TITANIUM DIOXIDE									
TOLUENE	0.5633								
TRICHLOROETHANE (METHYL CHLOROFORM)	0.021	0.12		100	2.04	0			
URANIUM (235, 236, 238)					5.6	0			
VINYL CHLORIDE						NA			
VOC	0.397				18.52	7.87			
WATER INPUT					NA				
XYLENE	0.819				2.1	0.52	16.24		
ZINC						0	20.3		
								4	

\* POC<sup>P</sup> average is for appropriate chemical group (e.g., ketones, alcohols, etc.)

\*\* Applies to air emissions only

\*\*\* Applies to air emissions only; factor is for 100-yr time period

NA = Data not available from on-line sources searched.

Equivalency factors for human health inhalation toxicity, terrestrial toxicity, and aquatic toxicity used in this LCIA incorporate both toxicity and persistence information (EPA, 1994) as recommended by SETAC (1993) for a Level 3 LCIA. The toxicity data used for each of these three impact criteria were as follows:

- human health inhalation toxicity - use the lowest rodent concentration lethal to 50% ( $LC_{50}$ ) of exposed animals in parts per million (ppm) experimental or structured-activity relationship (SAR) value and convert to a 4-hr acute test basis,
- terrestrial toxicity - use the lowest rodent dose lethal to 50% ( $LD_{50}$ ) of exposed animals in milligrams per kilogram (mg/kg) experimental or SAR value, and
- aquatic toxicity - use the lowest fish  $LC_{50}$  in milligrams per liter (mg/l) experimental or quantitative structure-activity relationship (QSAR) value for a 96-hr test.

In each case, the log of the toxicity data was used to establish a toxicity hazard value (HV). The HV was given a 0 or 5, respectively, if it was above or below a threshold value, as indicated in the EPA (1994) chemical ranking document. The HVs for toxicity data between these threshold values were determined from the formulas indicated in the EPA (1994) document. A similar approach was used to obtain the following three measures of persistence: biological oxygen demand (BOD) half-life, hydrolysis half-life, and bioconcentration factor (BCF). The natural log (ln) of the BOD and hydrolysis half-lives and the log of the BCF were used with the formulas in the EPA (1994) document to develop HVs from 1 to 2.5. The final equivalency factor for a chemical was based on the formula:

$$\text{Equivalency Factor} = (\text{toxicity HV})(\text{BOD HV} + \text{hydrolysis HV} + \text{BCF HV})$$

Thus, the maximum equivalency factor any chemical could have is (5) (2.5 + 2.5 + 2.5) = 37.5.

The equivalency factor for land use was the estimated density of each type of solid waste. Since the LCI data for solid wastes are expressed as weight/functional unit, multiplication of the weight and density gives an indication of the waste volume, and thus, the landfill volume required.

The equivalency factor for resource depletion was sustainability, which can be expressed as the world reserve base of a mineral or fossil fuel divided by the world annual production. The minerals information was obtained from the 1992 Minerals Yearbook: Volume I, Metals and Minerals (U.S. Bureau of Mines, 1992) or from more recent Minerals Commodity Summaries for individual minerals (U.S. Bureau of Mines, 1995a, 1995b, 1995c, 1995d, 1995e, 1995f, 1995g, 1995h, 1995i, 1995j, 1995k). The fuel data was based on U.S. reserves and production, and was obtained from the Energy Information Administration's Annual Energy Review for 1992 (U.S. Department of Energy, 1993). The sustainability value in years for a mineral or fuel was given an equivalency score of 1 to 5 based on the following scoring ranges:

Equivalency Score	Sustainability Scoring Ranges (years)
5	< 5
4	5-49
3	50-499
2	500-999
1	$\geq 1,000$

It should be noted that these scores do not take into account potential technological advancements for economically locating or mining natural resource deposits not currently included in the reserve base. Also, the scores do not consider the influence of increased recycling on

decreasing the demand for remaining reserves (e.g., aluminum recycling reducing the demand for bauxite).

#### **4.3 Economic Assessment**

The economic assessment is based on calculation of the cost in dollars for depainting and painting one functional unit (1,000 ft<sup>2</sup>) at Fort Eustis. The baseline case and the five alternative cases are evaluated. In addition to capital costs the annualized costs (consisting of the annual operating cost and amortization of the capital costs) are assessed. The primary cost components of the annualized costs are as follows:

- Raw Materials (includes topcoat, primer, thinner, and depainting abrasive)
- Utilities (electricity)
- Labor (operating, maintenance, and supervision)
- Operating Supplies
- Maintenance Supplies
- Laboratory Charges
- Plant Overhead
- Waste Disposal
- Insurance
- Regulatory Compliance
- Annual Operating Cost, and
- Capital Amortization.

#### **4.4 Performance Assessment**

In this section, all performance evaluation parameters (see Section 3) have been assigned a ranking system to discriminate between noticeable changes in performance. However, each ranking can include a range of performances. Since the baseline components discussed in this report will be compared to their alternatives in a subsequent report, it is likely that one of the baseline components and an alternative may be viewed to be alike in terms of practical considerations, and thus would fall within a given ranking. In this situation, if one system is believed to be slightly different, written descriptions will be used to describe the subtle differences. These descriptions have not been incorporated into the rankings discussed below.

Each set of evaluation parameters for application equipment, primers, or thinners was weighted in terms of importance. Therefore, a set that is weighted 2-1 would require a change of two ranking categories in the latter evaluation parameter to equal one change of rank in the higher weighted evaluation parameter.

##### ***4.4.1 Application Equipment***

Initially, the selection of application equipment that does not require thinning of the CARC topcoat was thought to provide the best potential for improvements in reducing emissions without affecting performance. It was theorized that selection of application equipment that uses higher atomization pressure could reduce or eliminate the need for thinning of the CARC topcoat. It was assumed that some loss in transfer efficiency might occur, but that this would be offset by the elimination or reduction in thinner usage.

Unfortunately, due to the nature of the topcoat and its method of curing, the degree of thinning required is very dependent upon the environmental conditions in which the topcoat is applied. The topcoat cures upon exposure to airborne moisture. Therefore, under high humidity conditions an opened can of topcoat might cure to a solid block overnight. This rapid cure resulted in a wide variety of opinions as to the level of thinning required. While some application equipment manufacturers (Seffick, 1995) and some users believe that it is possible to apply the CARC topcoat

without thinning, an equal number of opposing opinions were also found. At this time, no supporting literature has been found that can detail the techniques and equipment required to spray without thinning.

A second area of investigation was the use of improved housekeeping techniques. These techniques included using a gun cleaning bath that recycles solvents for multiple uses. Another technique would be the use of an inert gas "blanket" for purging moisture laden air from the topcoat cans to reduce the cure reaction in the can. This would increase the shelf-life of the topcoat and reduce the amount of thinner needed to maintain spraying viscosity. These alternatives were also eliminated due to a lack of information on the effectiveness of each technique.

The third and selected alternative was to reduce the amount of overspray by changing the application equipment. Electrostatic equipment was eliminated because of its inability to coat non-conductive surfaces. Therefore, it would be unable to coat the polymer sections of targets which are generally the most susceptible to chemical agent exposure.

There is a large pool of HVLP spraying equipment that shows a wide range of values of transfer efficiency. The turbine-powered Can-am system was chosen for analysis. This equipment was independently analyzed (Hughes Aircraft Company, 1991 as reported in Cavendar et al., 1994) against several other HVLP systems so side-by-side comparative information was available. This system is also currently used at several bases so additional user opinions could be obtained. The equipment uses a patented turbine technology to provide high volume low pressure air instead of the traditional method of using normal compressed air which passes through a conversion zone which in turn converts high pressure low volume air into HVLP. The turbine system thus reduces the amount of turbulence which decreases the amount of overspray. Bounceback of both HVLP technologies is minimal due to the low pressures involved.

#### **4.4.2 Primers**

Primer alternatives were limited to either selection of primers that fall within the same military specification (Mil-P-53022), but are made by alternative manufacturers, or to selection of a primer that falls within the only accepted alternative military specification (Mil-P-53030). Primers used for other materials were not considered because the information regarding adhesion to CARC topcoats would not be available. Due to the similarity of constituents used by different manufacturers when creating a primer for a given specification, it was decided that a review of the alternative specification would provide more substantial opportunity for improvement.

The alternative and the baseline are epoxy-polyamide systems. However, the alternative is water thinnable while the baseline can only be solvent thinned. While both primers do not generally require thinning for application, the baseline does require the use of a solvent for cleanup. The alternative can be cleaned with water. Unfortunately, the levels of solvent used for cleaning are not tracked as closely as those for thinning. Therefore, engineering judgements had to be made as to the level of reductions obtainable from the elimination of solvents for thinning. Since both systems have obtained military specification approval, they are expected to perform similarly in terms of adhesion and corrosion resistance.

#### **4.4.3 Thinners**

Thinner alternatives were again limited to selecting alternative manufacturers or selecting the only other currently used thinner which is classified under Federal Standard A-A-857B. Again, the choice was to select the alternative standard and not an alternative manufacturer. Thinner specifications describe the actual constituents required and the minimum or maximum levels which than can be used. Therefore, a comparison of thinners from different manufacturers would be unlikely to provide noticeable differences.

The baseline system is specifically designed as a thinner for aircraft coatings, while the alternative was designed as a dope and lacquer thinner. However, the lacquer thinner has been found to be an effective thinner of CARC by some who have used it (Ft. Eustis). The alternative thinner is currently being used at Ft. Eustis and believed to be effective. The performance of the thinners, like the primers, does appear to be dependent on the environmental conditions in which it is used.

## 5.0 Life Cycle Impact Assessment Results

### 5.1 Environmental Impact Characterization/Valuation

#### 5.1.1 Impact Characterization

The environmental impact significance of each resource and emission from the CARC LCI data shown in Appendix C was characterized (evaluated) using the equivalency factors reported in Table 3-3. The importance of each individual resource or chemical within an impact category was determined by multiplying the equivalency factor times the inventory value in pounds per functional unit. The results of these calculations for each resource or emission are provided as "factored scores" within each of the nine impact categories in Appendix D (Tables D-1 through D-9). These "factored scores" are the basis for the environmental impact valuation results discussed below, which are combined with the results for the economic and performance assessments in arriving at the conclusions regarding primary improvement opportunities that are described in Section 7.

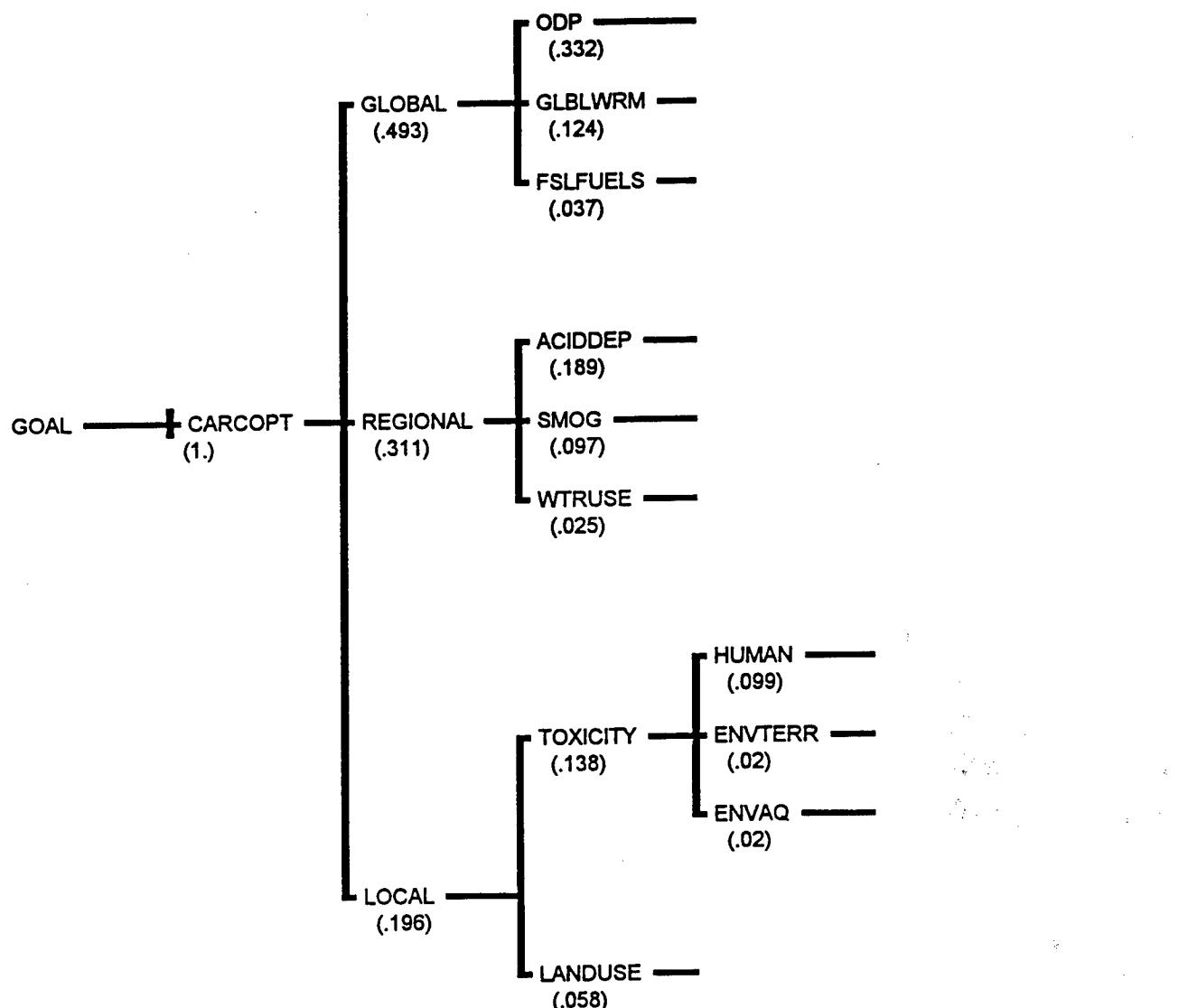
#### 5.1.2 Impact Valuation

In order to make comparisons between impact categories, the factored scores were normalized within an impact category and a valuation process was conducted on the nine impact categories. Normalization of "factored scores" was accomplished within an impact category by using the highest "factored score" in an impact category. The resulting "normalized factored scores" for each inventory item, including the total for all resources or chemicals in each impact category, are provided in Appendix D. The impact category totals from the tables in Appendix D are also shown in Table 6, which summarizes the valuation results.

Valuation of the nine impact categories was conducted using the AHP. A team of four Battelle staff representing substantially different scientific disciplines (chemical engineer, water chemist, civil engineer, and ecologist) were used to select preferred impact categories in a structured manner supported by the EC software package. A hierarchy "tree" was constructed as shown in Figure 5-1, with the goal to choose the most important environmental categories as the main "branches" and the nine individual impact categories selected for the streamlined CARC LCIA as the "leaves" on the tree. Impact categories were first broken down on a spatial basis, according to their influence on a global, regional, or local basis. The result of this process is the calculation of the weighting factors shown in Figure 5-2, which indicate the relative importance of each of the nine impact categories. These results indicate that the impacts of greatest concern to this group are ozone depletion (weight = 0.332), global warming (weight = 0.124), and smog creation (weight = 0.189). Although water use was included in the valuation process, it was not included in the LCIA, because net water used for each process in the lifecycle was not determined, because water availability is plentiful in most areas of the U.S. associated with CARC life-cycle operations, and because water is typically treated and reused or released to the environment.

When the normalized factored scores for each impact category are multiplied by the AHP weighting factors for the same category, the results provide a relative environmental impact ranking among impact categories for the baseline conditions (Table 5-1). Based on the normalized, weighted, factored scores, the three impact categories with the greatest impact for the CARC life-

cycle under baseline conditions are the same three impact categories identified to be of greatest concern by the AHP valuation process (i.e., ozone depletion = 0.362, acid deposition = 0.219, and global warming = 0.126). Thus, these are the impact areas with the greatest potential for reducing the overall environmental impact. However, it should be noted that all forms of toxicity (human, terrestrial, and aquatic) combined have a normalized, weighted, factored score of 0.316, which would make these combined impact subcategories second in overall potential for impact reduction.



#### Abbreviation

ACIDDEP	Acidic Materials Deposition
CARCOPT	Choose best CARC option
ENVAQ	Aquatic toxicity metrics
ENVTERR	Terrestrial toxicity metrics
FSLFUELS	Depletion of fossil fuels
GLBLWRM	Global warming potential
GLOBAL	Global level impacts
HUMAN	Various measures of human health toxicity
LANDUSE	Area of land "consumed"
LOCAL	Local scale impacts
ODP	Ozone depletion potential
REGIONAL	Regional to national scale impacts
SMOG	Photochemical smog formation potential
TOXICITY	Lethal or chronic toxicity effects
WTRUSE	Water consumption

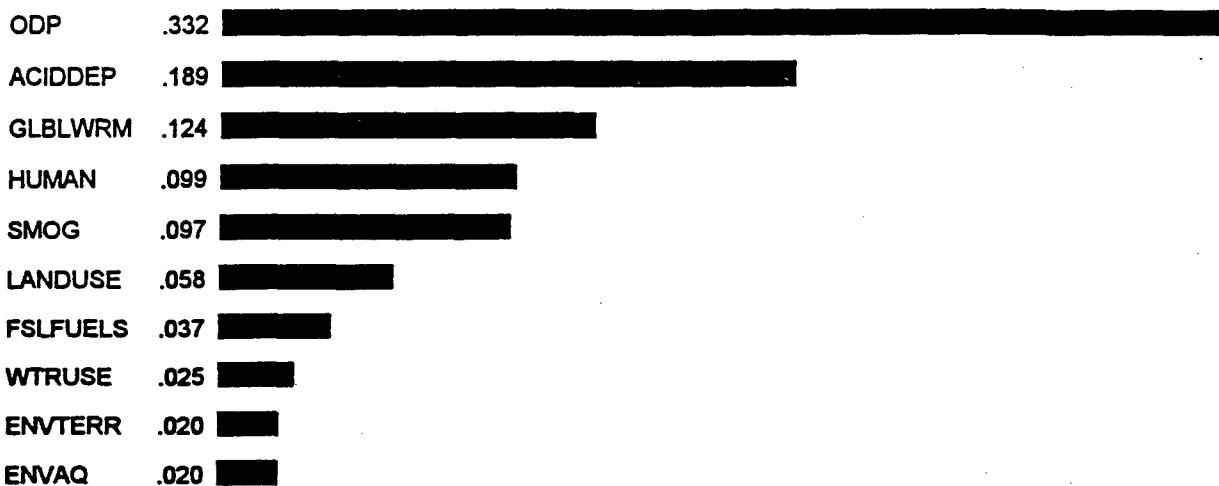
#### Definition

Figure 5-1. Results of impact category valuation by the AHP (distributive mode).

### Synthesis of Leaf Nodes with respect to GOAL

Distributive Mode

OVERALL INCONSISTENCY INDEX = 0.09



Abbreviation	Definition
ODP	Ozone Depletion Potential
ACIDDEP	Acidic Materials Deposition
GLBLWRM	Global Warming Potential
HUMAN	Various measures of human health toxicity
SMOG	Photochemical Smog Formation Potential
LANDUSE	Area of land "consumed"
FSLFUELS	Depletion of Fossil Fuels
WTRUSE	Water Consumption
ENVTER	Terrestrial toxicity metrics
ENVAQ	Aquatic toxicity metrics

Figure 5-2. Relative importance of nine primary impact categories based on AHP.

**Table 5-1. Life Cycle Impact Valuation Calculations**

CARCOPT	Spatial Scale	Impact Categories	AHP	Normalized Factored Score	Weighted, Normalized, Factored Score	Baseline Score
			Weighting Factor			1.275
GLOBAL		ODP	0.332	1.090	0.362	0.534
		GLBLWRM	0.124	1.013	0.126	
		FSLFUELS	0.037	1.263	0.047	
					0.334	
REGIONAL		ACIDDEP	0.189	1.198	0.226	0.334
		SMOG	0.097	1.114	0.108	
		WTRUSE	0.025		0.000	
					0.406	
LOCAL		TOXICITY			0.314	
		HUMAN	0.099	2.150	0.213	
		ENVTER	0.020	3.799	0.076	
		ENVAQ	0.020	1.280	0.026	
		LANDUSE	0.058	1.577	0.091	

## 5.2 Economic Assessment

The estimated costs for CARC depainting and painting at Fort Eustis are shown in Table 5-2.

**Table 5-2. Estimated Baseline FCI, Annual Operating Cost, and Annualized Costs**

Fixed Capital Investment (FCI), \$1,000	\$516
Annual operating cost, \$1,000	\$1,797/yr (or \$2,903/1,000 ft <sup>2</sup> )
Annualized cost, \$1,000	\$1,845/yr (or \$2,981/1,000 ft <sup>2</sup> )

### 5.2.1 Fixed Capital Investment

The estimated baseline FCI, \$516,000, was based on operations at Fort Eustis (Table 5-3).

**Table 5-3. Estimated Baseline Fixed Capital Investment**

Cost Item	Base Case	Basis
Purchased equipment (PE)	\$120,500	100% of purchased equipment (PE) cost
PE installation	54,225	45% of PE cost
Instrument and control	10,845	9% of PE cost
Piping	19,280	15% of PE cost
Electrical	12,050	10% of PE cost
Building	102,000	\$43 per ft <sup>2</sup> , 24 ft x 36 ft adjusted
Yard improvement	15,665	13% of PE cost
Service facilities	48,200	40% of PE cost
Land	0	Provided by base
<b>Total Direct Plant Cost</b>	<b>\$382,765</b>	
Engineering and supervision	39,765	33% of PE cost
Construction expense	46,995	39% of PE cost
<b>Total Direct and Indirect Costs</b>	<b>\$469,525</b>	
Contractors fees	23,476	5% of direct and indirect costs
Contingency	23,476	5% of direct and indirect costs
<b>Fixed Capital Investment</b>	<b>\$516,478</b>	

### 5.2.2 Annual Operating Cost

The estimated annual operating cost, \$1,797,000/yr as shown in Table 5-4, was based on operations typical of Fort Eustis.

Table 5-4. Estimated Baseline Annual Operating Cost

Cost Item	Base Case	Basis
<b>Raw Materials</b>		
Basecase topcoat	\$111,431	\$36/gal
Basecase primer	31,096	\$17/gal
Basecase thinner	24,437	\$15/gal
Depainting grit	7,993	\$0.25/lb
<b>Utility</b>		
Electricity	89,954	\$0.06/kWhr
<b>Labor</b>		
Operating	520,296	\$25/hr
Maintenance	13,524	3% of FCI
Supervision	78,044	15% of operating labor
<b>Operating Supplies</b>	78,044	15% of operating labor
<b>Maintenance Supplies</b>	18,031	4% of FCI
<b>Laboratory Charges</b>	78,044	15% of operating labor
<b>Plant Overhead</b>	367,118	60% of operating/maintenance labor
<b>Waste Disposal</b>		
Topcoat applied with HVLP gun	3,095	\$10/gal
BP primer	1,829	\$10/gal
Painting materials	4,924	100% of paint/primer disposal costs
Abrasive	42,904	\$0.58/lb
<b>Insurance</b>	4,508	1% of FCI
<b>Regulatory Compliance</b>	52,030	10% of operating labor
<b>Total Annual Operating Costs</b>	\$1,527,302	
per painted area	\$3,240	per 1,000 ft <sup>2</sup>
Capital amortization	42,220	9.37% FCI (11 yrs service @ 6%)
per painted area	\$90	per 1,000 ft <sup>2</sup>
<b>Total cost</b>	1,569,522	
per painted area	\$3,330	per 1,000 ft <sup>2</sup>

### 5.2.3 Annualized Cost

The estimated annualized cost, \$1,845,000/yr, is the sum of the annual operating cost and amortization. Details are provided in Table 5-5.

Table 5-5. Annualized Baseline Cost

Cost Element	Value	
	\$1,000/yr	\$1,000/ft <sup>2</sup>
Annual operating cost	1,797	2,903
Amortization	48	103
Annualized cost	1,845	2,981

### 5.3 Performance Assessment

#### 5.3.1 Application Equipment

The evaluation parameter results for the baseline application equipment used at Fort Eustis, which is the MACH 1 HVLP spray gun with a 97-95 nozzle made by Binks, are as follows:

- Transfer Efficiency (TE): Rating 65% (Martin, personal communication, 1995; Miller, personal communication, 1995; Hughes Aircraft Company, 1991 as reported in Cavendar et al., 1994)
- Surface Quality: Rating Acceptable (Martin, personal communication, 1995; Miller, personal communication, 1995; Hughes Aircraft Company, 1991 as reported in Cavendar et al., 1994)

Transfer efficiency shows the most potential for significant improvement. Significant improvement in surface quality is not considered to be needed.

#### 5.3.2 Primer

The baseline primer used at Fort Eustis is Mil-P-53022, which is a corrosion inhibiting, lead (Pb) and chromate free, epoxy coating, made by Niles. The evaluation parameter results for the baseline primer are as follows:

- Effect of Temperature and Humidity: Rating 3, minimal impact not seen as having practical significance (Hale, personal communication, 1995; Miller, personal communication, 1995)
- Cure Rate: Rating 3, cure rate had minimal affect on painting schedule (Hale, personal communication, 1995; Miller, personal communication, 1995)
- Surface Pretreatment Requirements: Rating 2, minimal cleaning with solvent rag required (Hale, personal communication, 1995; Miller, personal communication, 1995)
- Ease of Cleanup of the Primer: Rating 2, moderate effort required for cleanup (Hale, personal communication, 1995; Miller, personal communication, 1995)

Improvement in any of the three areas is possible. However, decreases in the primer's ranking in terms of effect of temperature and humidity would be viewed as most significant as is indicated by the weighting factor.

### **5.3.3 *Thinner***

The baseline thinner is Mil-T-81772B and is an aircraft coating made by CSD. The evaluation parameter results for the baseline thinner are as follows:

- Thinning Ratio or Thinner Effectiveness: 4:1 ratio for CARC:Thinner (Woody, personal communication, 1995; Miller, personal communication, 1995)
- Film Characteristics: Rating 3, minimal blemishes not believed significant (Woody, personal communication, 1995; Miller, personal communication, 1995)

The thinning ratio is seen as the most likely area for improvement.

## **6.0 Technical and Economic Evaluation of Improvements**

This section provides the reader with the basis for analyzing each of the alternatives according to each of the three evaluation dimensions individually and then through the use of the valuation results, collectively. The LCA inventory results are presented first because in some cases an alternative may be possible to analyze on the basis of a "less is better" strategy, in cases where all or most of the inventory categories are lower than those of the baseline or current system. When this occurs, interpretation using the impact results becomes unnecessary. However, this is rarely the situation so the impact-based results are presented next. Finally, the results for the cost and performance elements are provided.

### **6.1 Inventory Analysis**

Five alternatives were each evaluated against the baseline CARC system. Summary tables and graphs for the inventory results are provided below; additional details may be found in Appendix C. The baseline inventory results are summarized in Table 6-1. The first column in the table shows the total life-cycle aggregated information, the second column values are associated with the raw materials and manufacturing life-cycle stages, and the third column values are associated with depainting operations, application of the CARC at a base together with any disposal or recycling activities.

The first alternative utilized an alternative primer coupled with the baseline CARC topcoat and thinner. The baseline HVLP gun was used with both the primer and topcoat materials. The primary difference in the two primer formulations is the substitution of various solvents and the addition of more TiO<sub>2</sub> pigment to produce an alternative product capable of being water-thinned. The summary level inventory results shown in Table 6-2 indicate a combination of both increases and decreases in resource and energy consumption data relative to the baseline. A small decrease in resource consumption is noted for electricity, natural gas, steam, water, crude oil, refinery gases, oxygen and other minor components. Small increases were noted for fuel, sodium chloride, chlorine and the ilmenite and rumenite involved in the production of TiO<sub>2</sub>. Use of phosphate and zinc ores was eliminated. Major categories of air emissions showed decreases in CO<sub>2</sub>, VOC, PM, NO<sub>x</sub>, hydrocarbons, and CO. There were slight increases in chlorine and methane. Water usage and discharges were also generally reduced including mobile ions, sodium, chloride, oil and grease, and boron. Increased water discharges were noted for titanium dioxide, chlorine and heavy metals including cadmium, lead, and chromium. Hazardous solid wastes were reduced slightly while several chemicals were added to the list from the production of nitroethane including acetaldehyde, methanol, 2-nitropropane, acetone, acetonitrile, nitric acid, and ammonia. Because these chemical emissions are different than those for the baseline, it is difficult to unequivocally interpret the inventory results alone with respect to trace emissions to air and water.

**Table 6-1. Baseline CARC System Life Cycle Inventory Summary Results**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft^2	1,000		
<b>Resource and Energy Consumption</b>				
Electricity	BTU/FU	8.3E+05	8.3E+05	0.0E+00
Natural gas	BTU/FU	1.4E+07	1.4E+07	0.0E+00
Steam	BTU/FU	5.9E+05	5.9E+05	0.0E+00
Water	lb/FU	4.4E+04	4.4E+04	0.0E+00
Fuel	lb/FU	3.9E+04	3.9E+04	0.0E+00
Crude oil	lb/FU	2.8E+03	2.8E+03	0.0E+00
Bauxite	lb/FU	8.4E+01	8.4E+01	0.0E+00
Air	lb/FU	7.6E+01	7.6E+01	0.0E+00
Refinery gases	lb/FU	7.2E+01	7.2E+01	0.0E+00
Sodium Chloride	lb/FU	4.3E+01	4.3E+01	0.0E+00
Oxygen	lb/FU	1.5E+01	1.5E+01	0.0E+00
Silica	lb/FU	1.4E+01	1.4E+01	0.0E+00
Chlorine	lb/FU	1.3E+01	1.3E+01	0.0E+00
Zinc ore	lb/FU	8.3E+00	8.3E+00	0.0E+00
Rumenite	lb/FU	6.1E+00	6.1E+00	0.0E+00
Sulfuric acid	lb/FU	6.0E+00	6.1E+00	0.0E+00
Limestone	lb/FU	4.7E+00	4.7E+00	0.0E+00
Chrome oxide	lb/FU	4.6E+00	4.6E+00	0.0E+00
Soda ash	lb/FU	2.6E+00	2.6E+00	0.0E+00
Ilmenite	lb/FU	2.4E+00	2.4E+00	0.0E+00
Magnesium ore	lb/FU	2.2E+00	2.2E+00	0.0E+00
Phosphate ore	lb/FU	2.1E+00	2.1E+00	0.0E+00
Iron ore	lb/FU	1.3E+00	1.3E+00	0.0E+00
Coke	lb/FU	1.1E+00	1.1E+00	0.0E+00
Coibalt oxide	lb/FU	1.0E+00	1.0E+00	0.0E+00
Magnetite	lb/FU	4.0E-01	4.0E-01	0.0E+00
Sodium hydroxide	lb/FU	3.2E-01	3.2E-01	0.0E+00
Coal	lb/FU	2.9E-01	2.9E-01	0.0E+00
Starch	lb/FU	2.1E-01	2.1E-01	0.0E+00
SiAl	lb/FU	5.4E-02	5.4E-02	0.0E+00
Phosphoric acid	lb/FU	4.8E-02	4.8E-02	0.0E+00
Hydrocarbons C8 to C10	lb/FU	1.7E-02	1.7E-02	0.0E+00
Hydropotential	m^3-m/FU	6.9E-03	6.9E-03	0.0E+00
Sulfur dioxide	lb/FU	2.2E-03	2.2E-03	0.0E+00
Residual Fuel Oil	lb/FU	4.9E-06	4.9E-06	0.0E+00
Distillate Fuel Oil	lb/FU	4.2E-07	4.2E-07	0.0E+00
Uranium	lb/FU	4.2E-09	4.1E-09	0.0E+00
Proprietary Primer Ingredients	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Air Emissions</b>				
CO2	lb/FU	3.0E+02	3.0E+02	0.0E+00
Sox	lb/FU	2.2E+01	2.2E+01	0.0E+00
VOC	lb/FU	1.5E+01	1.5E+01	0.0E+00
NOx	lb/FU	6.1E+00	6.1E+00	0.0E+00
PM	lb/FU	6.0E+00	6.0E+00	0.0E+00
Hydrocarbons	lb/FU	3.3E+00	3.3E+00	0.0E+00
CO	lb/FU	1.4E+00	1.4E+00	0.0E+00
Chlorine	lb/FU	5.8E-01	5.8E-01	0.0E+00
MIAK	lb/FU	5.2E-01	7.1E-02	4.5E-01
Isobutyraldehyde	lb/FU	3.3E-01	3.3E-01	0.0E+00
PM10	lb/FU	3.1E-01	3.1E-01	0.0E+00
Methane	lb/FU	2.8E-01	2.8E-01	0.0E+00
Benzene	lb/FU	2.0E-01	2.0E-01	0.0E+00
Heavy Aromatics	lb/FU	2.0E-01	2.0E-01	0.0E+00
Butyl acetate	lb/FU	1.5E-01	0.0+00	1.5E-01
Toluene	lb/FU	1.3E-01	1.2E-01	1.4E-02
Acetaldehyde	lb/FU	8.9E-02	8.9E-02	0.0E+00
Heptane	lb/FU	8.6E-02	8.6E-02	0.0E+00

**Table 6-1. Baseline CARC System Life Cycle Inventory Summary Results (continued)**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
<b>Functional Unit (FU)</b>	<b>ft<sup>2</sup></b>	<b>1,000</b>		
Propane	lb/FU	7.4E-02	7.4E-02	0.0E+00
Hexane	lb/FU	6.7E-02	6.7E-02	0.0E+00
Naptha	lb/FU	6.6E-02	0.0E+00	6.6E-02
n-Butane	lb/FU	5.9E-02	5.9E-02	0.0E+00
MEK	lb/FU	5.9E-02	2.0E-02	3.8E-02
Octane	lb/FU	5.7E-02	5.7E-02	0.0E+00
Hexyl acetate	lb/FU	5.6E-02	0.0E+00	5.6E-02
Xylene	lb/FU	5.6E-02	9.4E-03	4.7E-02
Ethane	lb/FU	4.7E-02	4.7E-02	0.0E+00
Pentane	lb/FU	4.3E-02	4.2E-02	0.0E+00
Butyl alcohol	lb/FU	3.4E-02	0.0E+00	3.4E-02
Fluorine	lb/FU	2.8E-02	2.8E-02	0.0E+00
Cumene	lb/FU	2.7E-02	2.7E-02	0.0E+00
Organic Acids	lb/FU	2.5E-02	2.5E-02	0.0E+00
MIBK	lb/FU	2.3E-02	1.1E-02	1.2E-02
Aromatic hydrocarbons	lb/FU	2.3E-02	4.0E-04	2.3E-02
Phenol	lb/FU	2.2E-02	2.2E-02	0.0E+00
Formaldehyde	lb/FU	2.1E-02	2.1E-02	0.0E+00
Aldehydes	lb/FU	1.9E-02	1.9E-02	0.0E+00
C-7 cycloparaffins	lb/FU	1.2E-02	1.2E-02	0.0E+00
Acetone	lb/FU	8.3E-03	8.3E-03	0.0E+00
Ethylene dichloride	lb/FU	7.7E-03	7.7E-03	0.0E+00
HCN	lb/FU	6.7E-03	6.7E-03	0.0E+00
C-8 cycloparafins	lb/FU	4.4E-03	4.4E-03	0.0E+00
Ethyl chloride	lb/FU	3.0E-03	3.0E-03	0.0E+00
Iso-Butane	lb/FU	2.9E-03	2.9E-03	0.0E+00
Carbon tetrachloride	lb/FU	2.8E-03	2.8E-03	0.0E+00
Ethylene	lb/FU	2.8E-03	2.8E-03	0.0E+00
Trichloroethane	lb/FU	2.3E-03	2.3E-03	0.0E+00
Ethybenzene	lb/FU	2.2E-03	2.2E-03	0.0E+00
Vinyl chloride	lb/FU	1.4E-03	1.4E-03	0.0E+00
Chloroform	lb/FU	1.3E-03	1.3E-03	0.0E+00
Hydrochloric acid	lb/FU	1.3E-03	1.3E-03	0.0E+00
Lead	lb/FU	8.8E-04	8.8E-04	0.0E+00
Ammonia	lb/FU	6.2E-06	6.2E-06	0.0E+00
Kerosene	lb/FU	4.4E-09	4.4E-09	0.0E+00
Naphthalene	lb/FU	0.0E+00	0.0E+00	0.0E+00
Methanol	lb/FU	0.0E+00	0.0E+00	0.0E+00
Butyl cellosolve	lb/FU	0.0E+00	0.0E+00	0.0E+00
Nitric acid	lb/FU	0.0E+00	0.0E+00	0.0E+00
Bromotrifluoromethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Nitroethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Dichlorodifluoromethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Sulfuric acid	lb/FU	0.0E+00	0.0E+00	0.0E+00
Bromo-chlorodifluoromethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Acetonitrile	lb/FU	0.0E+00	0.0E+00	0.0E+00
2-nitropropane	lb/FU	0.0E+00	0.0E+00	0.0E+00
1,2-butylene	lb/FU	0.0E+00	0.0E+00	0.0E+00
Propylene	lb/FU	0.0E+00	0.0E+00	0.0E+00
MPK	lb/FU	0.0E+00	0.0E+00	0.0E+00
Isopropyl alcohol	lb/FU	0.0E+00	0.0E+00	0.0E+00
Propyl acetate	lb/FU	0.0E+00	0.0E+00	0.0E+00
Aliphatic hydrocarbons	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Wastewater Emissions</b>				
Wastewater	lb/FU	3.3E+03	3.3E+03	0.0E+00
WW reinj'd	lb/FU	1.6E+02	1.6E+02	0.0E+00
WW discharg.	lb/FU	7.1E+01	7.1E+01	0.0E+00
Mobile ions	lb/FU	3.5E+01	3.5E+01	0.0E+00

**Table 6-1. Baseline CARC System Life Cycle Inventory Summary Results (continued)**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
<b>Functional Unit (FU)</b>	<b>ft<sup>2</sup></b>	<b>1,000</b>		
WW Injected	lb/FU	2.3E+01	2.3E+01	0.0E+00
Sodium	lb/FU	1.4E+01	1.4E+01	0.0E+00
Chloride	lb/FU	1.1E+01	1.1E+01	0.0E+00
Oil and Grease	lb/FU	3.6E-01	3.6E-01	0.0E+00
titanium dioxide	lb/FU	1.3E-01	1.3E-01	0.0E+00
Chlorine	lb/FU	3.9E-02	3.9E-02	0.0E+00
Boron	lb/FU	1.5E-02	1.5E-02	0.0E+00
Cadmium	lb/FU	5.0E-03	5.0E-03	0.0E+00
Lead	lb/FU	1.8E-03	1.8E-03	0.0E+00
Benzene	lb/FU	7.1E-04	7.1E-04	0.0E+00
Aluminum	lb/FU	5.9E-04	5.9E-04	0.0E+00
Chromium	lb/FU	5.5E-04	5.5E-04	0.0E+00
Vanadium	lb/FU	1.3E-04	1.3E-04	0.0E+00
Copper	lb/FU	4.1E-05	4.1E-05	0.0E+00
Zinc	lb/FU	4.1E-05	4.1E-05	0.0E+00
Arsenic	lb/FU	3.0E-05	3.0E-05	0.0E+00
Iron	lb/FU	8.1E-06	8.1E-06	0.0E+00
Mercury	lb/FU	6.1E-06	6.1E-06	0.0E+00
Thallium	lb/FU	5.2E-06	5.2E-06	0.0E+00
Dissolved Solids	lb/FU	6.8E-07	6.8E-07	0.0E+00
Magnesium	lb/FU	1.2E-07	1.2E-07	0.0E+00
Sulfuric Acid	lb/FU	9.4E-08	9.4E-08	0.0E+00
COD	lb/FU	4.5E-09	4.5E-09	0.0E+00
Suspended Solids	lb/FU	2.3E-09	2.3E-09	0.0E+00
BOD	lb/FU	1.4E-09	1.4E-09	0.0E+00
Acid	lb/FU	7.6E-10	7.6E-10	0.0E+00
Oil	lb/FU	7.6E-10	7.6E-10	0.0E+00
Metals	lb/FU	3.8E-10	3.8E-10	0.0E+00
Phenol	lb/FU	3.8E-10	3.8E-10	0.0E+00
Sulfide	lb/FU	3.8E-10	3.8E-10	0.0E+00
Ammonia	lb/FU	0.0E+00	0.0E+00	0.0E+00
Hydrogen cyanide	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Solid Wastes</b>				
Hazardous Wastes	lb/FU	8.1E+01	2.3E+00	7.8E+01
Solid Wastes	lb/FU	6.2E+01	6.2E+01	0.0E+00
U238	lb/FU	5.4E-09	5.4E-09	0.0E+00
Fly Ash	lb/FU	2.0E-09	2.0E-09	0.0E+00
FGD Solids	lb/FU	7.9E-10	7.9E-10	0.0E+00
Bottom Ash	lb/FU	5.7E-10	5.7E-10	0.0E+00
Slag	lb/FU	2.2E-10	2.2E-10	0.0E+00
U235	lb/FU	4.5E-11	4.5E-11	0.0E+00
Pu (fissile)	lb/FU	3.7E-11	3.7E-11	0.0E+00
Fission Products	lb/FU	2.6E-11	2.6E-11	0.0E+00
Pu (nonfissile)	lb/FU	1.4E-11	1.4E-11	0.0E+00
U236	lb/FU	3.6E-12	3.6E-12	0.0E+00
Methanol	lb/FU	0.0E+00	0.0E+00	0.0E+00
Ammonia	lb/FU	0.0E+00	0.0E+00	0.0E+00
Nitric acid	lb/FU	0.0E+00	0.0E+00	0.0E+00
Naphthalene	lb/FU	0.0E+00	0.0E+00	0.0E+00
Formaldehyde	lb/FU	0.0E+00	0.0E+00	0.0E+00
2-nitropropane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Acetonitrile	lb/FU	0.0E+00	0.0E+00	0.0E+00
Acetone	lb/FU	0.0E+00	0.0E+00	0.0E+00
Acetaldehyde	lb/FU	0.0E+00	0.0E+00	0.0E+00
Hydrogen cyanide	lb/FU	0.0E+00	0.0E+00	0.0E+00

**Table 6-2. Alternative Primer CARC System Life Cycle Inventory Summary Results**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft <sup>2</sup>	1,000		
<b>Resource and Energy Consumption</b>				
Electricity	BTU/FU	7.6E+05	7.6E+05	0.0E+00
Natural gas	BTU/FU	1.3E+07	1.3E+07	0.0E+00
Steam	BTU/FU	5.4E+05	5.4E+05	0.0E+00
Fuel	lb/FU	6.4E+04	6.4E+04	0.0E+00
Water	lb/FU	4.0E+04	4.0E+04	0.0E+00
Crude oil	lb/FU	2.4E+03	2.4E+03	0.0E+00
Air	lb/FU	1.2E+02	1.2E+02	0.0E+00
Bauxite	lb/FU	8.4E+01	8.4E+01	0.0E+00
Refinery gases	lb/FU	6.7E+01	6.7E+01	0.0E+00
Sodium Chloride	lb/FU	4.3E+01	4.3E+01	0.0E+00
Chlorine	lb/FU	1.5E+01	1.5E+01	0.0E+00
Silica	lb/FU	1.3E+01	1.3E+01	0.0E+00
Oxygen	lb/FU	1.3E+01	1.3E+01	0.0E+00
Rumenite	lb/FU	9.9E+00	9.9E+00	0.0E+00
Sulfuric acid	lb/FU	8.2E+00	8.2E+00	0.0E+00
Limestone	lb/FU	4.7E+00	4.7E+00	0.0E+00
Chrome oxide	lb/FU	4.6E+00	4.6E+00	0.0E+00
Ilmenite	lb/FU	3.9E+00	3.9E+00	0.0E+00
Soda ash	lb/FU	2.6E+00	2.6E+00	0.0E+00
Magnesium ore	lb/FU	2.2E+00	2.2E+00	0.0E+00
Coke	lb/FU	1.8E+00	1.8E+00	0.0E+00
Iron ore	lb/FU	1.3E+00	1.3E+00	0.0E+00
Cobalt oxide	lb/FU	1.0E+00	1.0E+00	0.0E+00
Sodium hydroxide	lb/FU	5.3E-01	5.3E-01	0.0E+00
Magnetite	lb/FU	4.0E-01	4.0E-01	0.0E+00
Starch	lb/FU	2.1E-01	2.1E-01	0.0E+00
Hydrocarbons C8 to C10	lb/FU	9.2E-02	9.2E-02	0.0E+00
SiAl	lb/FU	8.8E-02	8.8E-02	0.0E+00
Phosphoric acid	m <sup>3</sup> -m/FU	4.8E-02	4.8E-02	0.0E+00
Hydropotential	lb/FU	6.3E-03	6.3E-03	0.0E+00
Sulfur dioxide	lb/FU	2.2E-03	2.2E-03	0.0E+00
Coal	lb/FU	1.6E-05	1.6E-05	0.0E+00
Residual Fuel Oil	lb/FU	4.4E-06	4.4E-06	0.0E+00
Distillate Fuel Oil	lb/FU	3.9E-07	3.9E-07	0.0E+00
Uranium	lb/FU	3.8E-09	3.8E-09	0.0E+00
Phosphate ore	lb/FU	0.0E+00	0.0E+00	0.0E+00
Proprietary Primer Ingredients	lb/FU	0.0E+00	0.0E+00	0.0E+00
Zinc ore	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Air Emissions</b>				
CO2	lb/FU	2.7E+02	2.7E+02	0.0E+00
Sox	lb/FU	2.1E+01	2.1E+01	0.0E+00
VOC	lb/FU	1.4E+01	1.4E+01	0.0E+00
PM	lb/FU	6.0E+00	6.0E+00	0.0E+00
Nox	lb/FU	5.9E+00	5.9E+00	0.0E+00
Hydrocarbons	lb/FU	2.9E+00	2.9E+00	0.0E+00
CO	lb/FU	7.9E-01	7.9E-01	0.0E+00
Chlorine	lb/FU	5.9E-01	5.9E-01	0.0E+00
Isobutylraldehyde	lb/FU	3.3E-01	3.3E-01	0.0E+00
PM10	lb/FU	3.1E-01	3.1E-01	0.0E+00
Methane	lb/FU	2.4E-01	2.4E-01	0.0E+00
Benzene	lb/FU	2.0E-01	2.0E-01	0.0E+00
Heavy Aromatics	lb/FU	2.0E-01	2.0E-01	0.0E+00
Toulene	lb/FU	1.1E-01	1.1E-01	0.0E+00
Heptane	lb/FU	7.6E-02	7.6E-02	0.0E+00
MIAK	lb/FU	7.1E-02	7.1E-02	0.0E+00
Propane	lb/FU	6.6E-02	6.6E-02	0.0E+00
Hexane	lb/FU	5.9E-02	5.9E-02	0.0E+00

Table 6-2. Baseline CARC System Life Cycle Inventory Summary Results (continued)

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft <sup>2</sup>	1,000		
n-Butane	lb/FU	5.2E-02	5.2E-02	0.0E +00
Octane	lb/FU	5.1E-02	5.1E-02	0.0E +00
Xylene	lb/FU	4.3E-02	4.3E-02	0.0E +00
Ethane	lb/FU	4.2E-02	4.2E-02	0.0E +00
Butyl alcohol	lb/FU	4.2E-02	0.0E +00	4.2E-02
Acetaldehyde	lb/FU	4.0E-02	4.0E-02	0.0E +00
Aromatic hydrocarbons	lb/FU	3.8E-02	0.0E +00	3.8E-02
Pentane	lb/FU	3.7E-02	3.7E-02	0.0E +00
Cumene	lb/FU	2.3E-02	2.3E-02	0.0E +00
Organic Acids	lb/FU	2.2E-02	2.2E-02	0.0E +00
Phenol	lb/FU	2.1E-02	2.1E-02	0.0E +00
MEK	lb/FU	2.0E-02	2.0E-02	0.0E +00
Formaldehyde	lb/FU	1.9E-02	1.9E-02	0.0E +00
Aldehydes	lb/FU	1.7E-02	1.7E-02	0.0E +00
C-7 cycloparaffins	lb/FU	1.1E-02	1.1E-02	0.0E +00
Acetone	lb/FU	1.4E-03	1.4E-03	0.0E +00
HCN	lb/FU	6.8E-03	6.8E-03	0.0E +00
Ethylbenzene	lb/FU	4.5E-03	4.5E-03	0.0E +00
C-8 cycloparaffins	lb/FU	3.9E-03	3.9E-03	0.0E +00
Nitroethane	lb/FU	3.9E-03	0.0E +00	0.0E +00
Iso-Butane	lb/FU	2.6E-03	2.6E-03	3.9E-03
Hydrochloric acid	lb/FU	1.9E-03	1.9E-03	0.0E +00
Dichlorodifluoromethane	lb/FU	1.1E-03	1.1E-03	0.0E +00
Ammonia	lb/FU	8.9E-04	8.9E-04	0.0E +00
Naphthalene	lb/FU	6.43E-04	6.43E-04	0.0E +00
2-nitropropane	lb/FU	6.1E-04	6.1E-04	0.0E +00
Ethylene	lb/FU	5.6E-04	5.6E-04	0.0E +00
Acetonitrile	lb/FU	2.4E-05	2.4E-05	0.0E +00
Methanol	lb/FU	1.9E-05	1.9E-05	0.0E +00
Bromotrifluoromethane	lb/FU	8.3E-06	8.3E-06	0.0E +00
Nitric acid	lb/FU	5.5E-06	5.5E-06	0.0E +00
Bromochlorodifluoromethane	lb/FU	2.2E-06	2.2E-06	0.0E +00
1,2-butylene	lb/FU	7.0E-07	7.0E-07	0.0E +00
Kerosene	lb/FU	4.1E-09	4.1E-09	0.0E +00
Lead	lb/FU	9.1E-11	9.1E-11	0.0E +00
Hexyl acetate	lb/FU	0.0E +00	0.0E +00	0.0E +00
Propylene	lb/FU	0.0E +00	0.0E +00	0.0E +00
Sulfuric acid	lb/FU	0.0E +00	0.0E +00	0.0E +00
Ethyl chloride	lb/FU	0.0E +00	0.0E +00	0.0E +00
Vinyl chloride	lb/FU	0.0E +00	0.0E +00	0.0E +00
Isopropyl alcohol	lb/FU	0.0E +00	0.0E +00	0.0E +00
MPK	lb/FU	0.0E +00	0.0E +00	0.0E +00
Propyl acetate	lb/FU	0.0E +00	0.0E +00	0.0E +00
Naptha	lb/FU	0.0E +00	0.0E +00	0.0E +00
Butyl acetate	lb/FU	0.0E +00	0.0E +00	0.0E +00
Fluorine	lb/FU	0.0E +00	0.0E +00	0.0E +00
MIBK	lb/FU	0.0E +00	0.0E +00	0.0E +00
Trichloroethane	lb/FU	0.0E +00	0.0E +00	0.0E +00
Carbon tetrachloride	lb/FU	0.0E +00	0.0E +00	0.0E +00
Chloroform	lb/FU	0.0E +00	0.0E +00	0.0E +00
Butyl cellosolve	lb/FU	0.0E +00	0.0E +00	0.0E +00
Ethylene dichloride	lb/FU	0.0E +00	0.0E +00	0.0E +00
Aliphatic hydrocarbons	lb/FU	0.0E +00	0.0E +00	0.0E +00
<b>Wastewater Emissions</b>				
Wastewater	lb/FU	2.9E +03	2.9E +03	0.0E +00
WW Rein'd	lb/FU	1.4E +02	1.4E +02	0.0E +00
WW Discharg.	lb/FU	6.3E +01	6.3E +01	0.0E +00
Mobile ions	lb/FU	3.1E +01	3.1E +01	0.0E +00

**Table 6-2. Baseline CARC System Life Cycle Inventory Summary Results (continued)**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft <sup>2</sup>	1,000		
WW Injected	lb/FU	2.1E+01	2.1E+01	0.0E+00
Sodium Chloride	lb/FU	1.3E+01	1.3E+01	0.0E+00
Oil and Grease	lb/FU	1.0E+01	1.0E+01	0.0E+00
Titanium dioxide	lb/FU	3.1E-01	3.1E-01	0.0E+00
Chlorine	lb/FU	2.1E-01	2.1E-01	0.0E+00
Boron	lb/FU	1.2E-01	1.2E-01	0.0E+00
Cadmium	lb/FU	8.0E-03	8.0E-03	0.0E+00
Lead	lb/FU	2.9E-03	2.9E-03	0.0E+00
Aluminum	lb/FU	9.7E-04	9.7E-04	0.0E+00
Chromium	lb/FU	8.9E-04	8.9E-04	0.0E+00
Benzene	lb/FU	6.3E-04	6.3E-04	0.0E+00
Vanadium	lb/FU	2.1E-04	2.1E-04	0.0E+00
Copper	lb/FU	6.8E-05	6.8E-05	0.0E+00
Zinc	lb/FU	6.8E-05	6.8E-05	0.0E+00
Arsenic	lb/FU	2.6E-05	2.6E-05	0.0E+00
Iron	lb/FU	7.4E-06	7.4E-06	0.0E+00
Mercury	lb/FU	5.8E-06	5.8E-06	0.0E+00
Thallium	lb/FU	4.6E-06	4.6E-06	0.0E+00
Ammonia	lb/FU	1.7E-06	1.7E-06	0.0E+00
Dissolved Solids	lb/FU	6.3E-07	6.3E-07	0.0E+00
Magnesium	lb/FU	1.9E-07	1.9E-07	0.0E+00
Hydrogen cyanide	lb/FU	1.2E-07	1.2E-07	0.0E+00
Sulfuric Acid	lb/FU	8.6E-08	8.6E-08	0.0E+00
COD	lb/FU	4.1E-09	4.1E-09	0.0E+00
Suspended Solids	lb/FU	2.1E-09	2.1E-09	0.0E+00
BOD	lb/FU	1.3E-09	1.3E-09	0.0E+00
Oil	lb/FU	6.9E-10	6.9E-10	0.0E+00
Acid	lb/FU	6.9E-10	6.9E-10	0.0E+00
Metals	lb/FU	3.5E-10	3.5E-10	0.0E+00
Sulfide	lb/FU	3.5E-10	3.5E-10	0.0E+00
Phenol	lb/FU	3.5E-10	3.5E-10	0.0E+00
<b>Solid Wastes</b>				
Hazardous Wastes	lb/FU	7.9E+01	9.8E-01	7.8E+01
Solid Wastes	lb/FU	6.2E+01	6.2E+01	0.0E+00
Acetaldehyde	lb/FU	1.0E-02	1.0E-02	0.0E+00
Methanol	lb/FU	9.2E-03	9.2E-03	0.0E+00
2-nitropropane	lb/FU	8.1E-03	8.1E-03	0.0E+00
Acetone	lb/FU	5.6E-03	5.6E-03	0.0E+00
Acetonitrile	lb/FU	4.6E-03	4.6E-03	0.0E+00
Nitric acid	lb/FU	6.4E-04	6.4E-04	0.0E+00
Ammonia	lb/FU	1.4E-04	1.4E-04	0.0E+00
Formaldehyde	lb/FU	8.0E-05	8.0E-05	0.0E+00
Naphthalene	lb/FU	6.6E-06	6.6E-06	0.0E+00
Hydrogen cyanide	lb/FU	6.6E-06	6.6E-06	0.0E+00
U238	lb/FU	4.9E-09	4.9E-09	0.0E+00
Fly Ash	lb/FU	1.9E-09	1.9E-09	0.0E+00
FGD Solids	lb/FU	7.2E-10	7.2E-10	0.0E+00
Bottom Ash	lb/FU	5.2E-10	5.2E-10	0.0E+00
Slag	lb/FU	2.0E-10	2.0E-10	0.0E+00
U235	lb/FU	4.2E-11	4.2E-11	0.0E+00
Pu (fissile)	lb/FU	3.4E-11	3.4E-11	0.0E+00
Fission Products	lb/FU	2.4E-11	2.4E-11	0.0E+00
Pu (nonfissile)	lb/FU	1.3E-11	1.3E-11	0.0E+00
U236	lb/FU	3.3E-12	3.3E-12	0.0E+00

The second alternative involved the substitution of the turbine HVLP gun for the standard HVLP gun. All of the materials used were those included in the baseline scenario. This alternative resulted in significantly lower levels of resource consumption, energy usage, and emissions than the baseline (Table 6-3). This is a direct result of the more efficient use of materials and energy. Because a much higher percentage of the CARC sprayed actually ends up on the vehicle surface, not only are the emissions during the application reduced but also the upstream consequences of manufacturing materials that never get applied are eliminated.

The third alternative combines the alternative primer with the alternative gun (Table 6-4). As might be expected, this option shows even greater reductions in energy and resources than the previous alternatives where the primer and gun substitutions were considered independently. In the case of emissions, the picture was mixed. The alternative primer emissions comprise both different compounds than are present in the baseline primer and different amounts of those compounds that are ingredients in common. Thus, the inventory data alone cannot be interpreted in an unequivocal fashion. For those emissions that are in common, some decreased and some increased. The overall amounts decreased but by a smaller amount than for the previous alternative.

The fourth alternative utilized an alternative thinner along with the baseline topcoat, primer, and gun (Table 6-5). The primary difference in the thinners is a reduction and substitution of the acetate-based solvents and the addition of more alcohol-based solvents. The results for this scenario indicate reduced resource and energy demands for electricity, steam, water, crude oil, bauxite, air, residual and distillate fuel oils compared to the data shown for the baseline. Major categories of air emissions showed reduced CO<sub>2</sub> and hydrocarbons with slightly increased SO<sub>x</sub>. The data also showed lower water usage and discharge rates in addition to reduced mobile ions, chloride, oil and grease and other minor constituents. Solid wastes showed reductions in the minor categories, but little change was indicated in the amounts of general hazardous and solid wastes.

**Table 6-3. Alternative Gun CARC System Life Cycle Inventory Summary Results**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft <sup>2</sup>	1,000		
<b>Resource and Energy Consumption</b>				
Electricity	BTU/FU	6.1E+05	6.1E+05	0.0E+00
Natural gas	BTU/FU	1.0E+07	1.0E+07	0.0E+00
Steam	BTU/FU	4.6E+05	4.6E+05	0.0E+00
Water	lb/FU	3.2E+04	3.2E+04	0.0E+00
Fuel	lb/FU	2.8E+04	2.8E+04	0.0E+00
Crude oil	lb/FU	2.0E+03	2.0E+03	0.0E+00
Bauxite	lb/FU	8.4E+01	8.4E+01	0.0E+00
Air	lb/FU	5.5E+01	5.5E+01	0.0E+00
Refinery gases	lb/FU	5.2E+01	5.2E+01	0.0E+00
Sodium Chloride	lb/FU	3.1E+01	3.1E+01	0.0E+00
Oxygen	lb/FU	1.1E+01	1.1E+01	0.0E+00
Silica	lb/FU	9.9E+00	9.9E+00	0.0E+00
Chlorine	lb/FU	9.5E+00	9.5E+00	0.0E+00
Zinc ore	lb/FU	6.0E+00	6.0E+00	0.0E+00
Limestone	lb/FU	4.7E+00	4.7E+00	0.0E+00
Rumenite	lb/FU	4.4E+00	4.4E+00	0.0E+00
Sulfuric acid	lb/FU	4.4E+00	4.4E+00	0.0E+00
Chrome oxide	lb/FU	3.3E+00	3.3E+00	0.0E+00
Soda ash	lb/FU	2.6E+00	2.6E+00	0.0E+00
Ilmenite	lb/FU	1.7E+00	1.7E+00	0.0E+00
Magnesium ore	lb/FU	1.6E+00	1.6E+00	0.0E+00
Phosphate ore	lb/FU	1.5E+00	1.5E+00	0.0E+00
Iron ore	lb/FU	9.3E-01	9.3E-01	0.0E+00
Coke	lb/FU	7.7E-01	7.7E-01	0.0E+00
Cobalt oxide	lb/FU	7.2E-01	7.2E-01	0.0E+00
Magnetite	lb/FU	2.9E-01	2.9E-01	0.0E+00
Sodium hydroxide	lb/FU	2.3E-01	2.3E-01	0.0E+00
Coal	lb/FU	2.1E-01	2.1E-01	0.0E+00
Starch	lb/FU	2.1E-01	2.1E-01	0.0E+00
SiAl	lb/FU	3.9E-02	3.9E-02	0.0E+00
Phosphoric acid	lb/FU	3.4E-02	3.4E-02	0.0E+00
Hydrocarbons C8 to C10	lb/FU	1.2E-02	1.2E-02	0.0E+00
Hydropotential	m <sup>3</sup> -m/FU	5.0E-03	5.0E-03	0.0E+00
Sulfur dioxide	lb/FU	1.6E-03	1.6E-03	0.0E+00
Residual Fuel Oil	lb/FU	3.5E-06	3.5E-06	0.0E+00
Distillate Fuel Oil	lb/FU	3.1E-07	3.1E-07	0.0E+00
Uranium	lb/FU	3.0E-09	3.0E-09	0.0E+00
Proprietary Primer Ingredients	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Air Emissions</b>				
CO2	lb/FU	2.2E+02	2.2E+02	0.0E+00
SOx	lb/FU	2.1E+01	2.1E+01	0.0E+00
VOC	lb/FU	1.1E+01	1.1E+01	0.0E+00
PM	lb/FU	4.4E+00	4.4E+00	0.0E+00
NOx	lb/FU	4.4E+00	4.4E+00	0.0E+00
Hydrocarbons	lb/FU	2.4E+00	2.4E+00	0.0E+00
CO	lb/FU	1.0E+00	1.0E+00	0.0E+00
Chlorine	lb/FU	4.2E-01	4.2E-01	0.0E+00
PM10	lb/FU	2.9E-01	2.9E-01	0.0E+00
MAIK	lb/FU	2.9E-01	5.1E-02	2.4E-01
Isobutylaldehyde	lb/FU	2.6E-01	2.6E-01	0.0E+00
Methane	lb/FU	2.0E-01	2.0E-01	0.0E+00
Benzene	lb/FU	1.5E-01	1.5E-01	0.0E+00
Heavy Aromatics	lb/FU	1.4E-01	1.4E-01	0.0E+00
Toluene	lb/FU	9.8E-02	9.0E-02	8.7E-03
Butyl acetate	lb/FU	7.9E-02	0.0E+00	7.9E-02
Acetaldehyde	lb/FU	6.6E-02	6.6E-02	0.0E+00
Heptane	lb/FU	6.3E-02	6.3E-02	0.0E+00
Propane	lb/FU	5.4E-02	5.4E-02	0.0E+00
Hexane	lb/FU	4.9E-02	4.9E-02	0.0E+00
n-Butane	lb/FU	4.3E-02	4.3E-02	0.0E+00
Octane	lb/FU	4.2E-02	4.2E-02	0.0E+00

**Table 6-3. Alternative Gun CARC System Life Cycle Inventory Summary Results (continued)**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft <sup>2</sup>	1,000		
MEK	lb/FU	4.0E-02	1.6E-02	2.4E-02
Hexyl acetate	lb/FU	3.5E-02	0.0E+00	3.5E-02
Ethane	lb/FU	3.5E-02	3.5E-02	0.0E+00
Naphtha	lb/FU	3.4E-02	0.0E+00	3.4E-02
Xylene	lb/FU	3.2E-02	6.8E-03	2.5E-02
Pentane	lb/FU	3.0E-02	3.0E-02	0.0E+00
Fluorine	lb/FU	2.0E-02	2.0E-02	0.0E+00
Cumene	lb/FU	1.9E-02	1.9E-02	0.0E+00
Organic Acids	lb/FU	1.8E-02	1.8E-02	0.0E+00
Butyl alcohol	lb/FU	1.8E-02	0.0E+00	1.8E-02
Phenol	lb/FU	1.6E-02	1.6E-02	0.0E+00
Formaldehyde	lb/FU	1.5E-02	1.5E-02	0.0E+00
MIBK	lb/FU	1.4E-02	8.0E-03	6.4E-03
Aldehydes	lb/FU	1.4E-02	1.4E-02	0.0E+00
Aromatic hydrocarbons	lb/FU	1.2E-02	2.9E-04	1.2E-02
C-7 cycloparaffins	lb/FU	8.8E-03	8.8E-03	0.0E+00
Acetone	lb/FU	6.1E-03	6.1E-03	0.0E+00
Ethylene dichloride	lb/FU	5.6E-03	5.6E-03	0.0E+00
HCN	lb/FU	4.9E-03	4.9E-03	0.0E+00
C-8 cycloparaffins	lb/FU	3.2E-03	3.2E-03	0.0E+00
Ethyl chloride	lb/FU	2.2E-03	2.2E-03	0.0E+00
Iso-Butane	lb/FU	2.1E-03	2.1E-03	0.0E+00
Ethylene	lb/FU	2.1E-03	2.1E-03	0.0E+00
Carbon tetrachloride	lb/FU	2.0E-03	2.0E-03	0.0E+00
Trichloroethane	lb/FU	1.7E-03	1.7E-03	0.0E+00
Ethylbenzene	lb/FU	1.6E-03	1.6E-03	0.0E+00
Vinyl chloride	lb/FU	1.0E-03	1.0E-03	0.0E+00
Chloroform	lb/FU	9.7E-04	9.7E-04	0.0E+00
Hydrochloric acid	lb/FU	9.5E-04	9.5E-04	0.0E+00
Lead	lb/FU	6.3E-04	6.3E-04	0.0E+00
Ammonia	lb/FU	4.5E-06	4.5E-06	0.0E+00
Kerosene	lb/FU	3.2E-09	3.2E-09	0.0E+00
Naphthalene	lb/FU	0.0E+00	0.0E+00	0.0E+00
Methanol	lb/FU	0.0E+00	0.0E+00	0.0E+00
Butyl cellosolve	lb/FU	0.0E+00	0.0E+00	0.0E+00
Nitric acid	lb/FU	0.0E+00	0.0E+00	0.0E+00
Bromotrifluoromethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Nitroethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Dichlorodifluoromethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Sulfuric acid	lb/FU	0.0E+00	0.0E+00	0.0E+00
Bromo-chlorodifluoromethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Acetonitrile	lb/FU	0.0E+00	0.0E+00	0.0E+00
2-nitropropane	lb/FU	0.0E+00	0.0E+00	0.0E+00
1,2-butylene	lb/FU	0.0E+00	0.0E+00	0.0E+00
Propylene	lb/FU	0.0E+00	0.0E+00	0.0E+00
MPK	lb/FU	0.0E+00	0.0E+00	0.0E+00
Isopropyl alcohol	lb/FU	0.0E+00	0.0E+00	0.0E+00
Propyl acetate	lb/FU	0.0E+00	0.0E+00	0.0E+00
Aliphatic hydrocarbons	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Wastewater Emissions</b>				
Wastewater	lb/FU	2.4E+03	2.4E+03	0.0E+00
WW Rein'd	lb/FU	1.2E+02	1.2E+02	0.0E+00
WW Discharg.	lb/FU	5.2E+01	5.2E+01	0.0E+00
Mobile ions	lb/FU	2.5E+01	2.5E+01	0.0E+00
WW Injected	lb/FU	1.7E+01	1.7E+01	0.0E+00
Sodium	lb/FU	1.1E+01	1.1E+01	0.0E+00
Chloride	lb/FU	8.3E+00	8.3E+00	0.0E+00
Oil and Grease	lb/FU	2.6E-01	2.6E-01	0.0E+00
Titanium dioxide	lb/FU	9.4E-02	9.4E-02	0.0E+00
Chlorine	lb/FU	2.8E-02	2.8E-02	0.0E+00
Boron	lb/FU	1.1E-02	1.1E-02	0.0E+00
Cadmium	lb/FU	3.6E-03	3.6E-03	0.0E+00

**Table 6-3. Alternative Gun CARC System Life Cycle Inventory Summary Results (continued)**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft^2	1,000		
Lead	lb/FU	1.3E-03	1.3E-03	0.0E+00
Benzene	lb/FU	5.2E-04	5.2E-04	0.0E+00
Aluminum	lb/FU	4.3E-04	4.3E-04	0.0E+00
Chromium	lb/FU	4.0E-04	4.0E-04	0.0E+00
Vanadium	lb/FU	9.4E-05	9.4E-05	0.0E+00
Copper	lb/FU	3.0E-05	3.0E-05	0.0E+00
Zinc	lb/FU	3.0E-05	3.0E-05	0.0E+00
Arsenic	lb/FU	2.2E-05	2.2E-05	0.0E+00
Iron	lb/FU	5.9E-06	5.9E-06	0.0E+00
Mercury	lb/FU	4.4E-06	4.4E-06	0.0E+00
Thallium	lb/FU	3.8E-06	3.8E-06	0.0E+00
Dissolved Solids	lb/FU	5.0E-07	5.0E-07	0.0E+00
Magnesium	lb/FU	8.5E-08	8.5E-08	0.0E+00
Sulfuric Acid	lb/FU	6.8E-08	6.8E-08	0.0E+00
COD	lb/FU	3.3E-09	3.3E-09	0.0E+00
Suspended Solids	lb/FU	1.7E-09	1.7E-09	0.0E+00
BOD	lb/FU	9.9E-10	9.9E-10	0.0E+00
Acid	lb/FU	5.5E-10	5.5E-10	0.0E+00
Oil	lb/FU	5.5E-10	5.5E-10	0.0E+00
Metals	lb/FU	2.7E-10	2.7E-10	0.0E+00
Phenol	lb/FU	2.7E-10	2.7E-10	0.0E+00
Sulfide	lb/FU	2.7E-10	2.7E-10	0.0E+00
Ammonia	lb/FU	0.0E+00	0.0E+00	0.0E+00
Hydrogen cyanide	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Solid Wastes</b>				
Hazardous Wastes	lb/FU	8.0E+01	1.7E+00	7.8E+01
Solid Wastes	lb/FU	5.3E+01	5.3E+01	0.0E+00
U238	lb/FU	3.9E-09	3.9E-09	0.0E+00
Fly Ash	lb/FU	1.5E-09	1.5E-09	0.0E+00
FGD Solids	lb/FU	5.7E-10	5.7E-10	0.0E+00
Bottom Ash	lb/FU	4.1E-10	4.1E-10	0.0E+00
Slag	lb/FU	1.6E-10	1.6E-10	0.0E+00
U235	lb/FU	3.3E-11	3.3E-11	0.0E+00
Pu (fissile)	lb/FU	2.7E-11	2.7E-11	0.0E+00
Fission Products	lb/FU	1.9E-11	1.9E-11	0.0E+00
Pu (nonfissile)	lb/FU	1.0E-11	1.0E-11	0.0E+00
U236	lb/FU	2.6E-12	2.6E-12	0.0E+00
Methanol	lb/FU	0.0E+00	0.0E+00	0.0E+00
Ammonia	lb/FU	0.0E+00	0.0E+00	0.0E+00
Nitric acid	lb/FU	0.0E+00	0.0E+00	0.0E+00
Naphthalene	lb/FU	0.0E+00	0.0E+00	0.0E+00
Formaldehyde	lb/FU	0.0E+00	0.0E+00	0.0E+00
2-nitropropane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Acetonitrile	lb/FU	0.0E+00	0.0E+00	0.0E+00
Acetone	lb/FU	0.0E+00	0.0E+00	0.0E+00
Acetaldehyde	lb/FU	0.0E+00	0.0E+00	0.0E+00
Hydrogen cyanide	lb/FU	0.0E+00	0.0E+00	0.0E+00

**Table 6-4. Alternative Primer & Gun CARC System Life Cycle Inventory Summary Results**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft^2	1,000		
<b>Resource and Energy Consumption</b>				
Electricity	BTU/FU	5.6E+05	5.6E+05	0.0E+00
Natural gas	BTU/FU	9.3E+06	9.3E+06	0.0E+00
Steam	BTU/FU	4.3E+05	4.3E+05	0.0E+00
Fuel	lb/FU	4.6E+04	4.6E+04	0.0E+00
Water	lb/FU	2.9E+04	2.9E+04	0.0E+00
Crude oil	lb/FU	1.8E+03	1.8E+03	0.0E+00
Air	lb/FU	9.0E+01	9.0E+01	0.0E+00
Bauxite	lb/FU	8.4E+01	8.4E+01	0.0E+00
Refinery gases	lb/FU	4.9E+01	4.9E+01	0.0E+00
Sodium Chloride	lb/FU	3.1E+01	3.1E+01	0.0E+00
Chlorine	lb/FU	1.1E+01	1.1E+01	0.0E+00
Silica	lb/FU	9.7E+00	9.7E+00	0.0E+00
Oxygen	lb/FU	9.6E+00	9.6E+00	0.0E+00
Rumenite	lb/FU	7.2E+00	7.2E+00	0.0E+00
Sulfuric acid	lb/FU	5.9E+00	5.9E+00	0.0E+00
Limestone	lb/FU	4.7E+00	4.7E+00	0.0E+00
Chrome oxide	lb/FU	3.3E+00	3.3E+00	0.0E+00
Ilmenite	lb/FU	2.8E+00	2.8E+00	0.0E+00
Soda ash	lb/FU	2.6E+00	2.6E+00	0.0E+00
Magnesium ore	lb/FU	1.6E+00	1.6E+00	0.0E+00
Coke	lb/FU	1.3E+00	1.3E+00	0.0E+00
Iron ore	lb/FU	9.7E-01	9.7E-01	0.0E+00
Cobalt oxide	lb/FU	7.2E-01	7.2E-01	0.0E+00
Sodium hydroxide	lb/FU	3.8E-01	3.8E-01	0.0E+00
Magnetite	lb/FU	2.9E-01	2.9E-01	0.0E+00
Starch	lb/FU	2.1E-01	2.1E-01	0.0E+00
Hydrocarbons C8 to C10	lb/FU	6.6E-02	6.6E-02	0.0E+00
SiAl	lb/FU	6.3E-02	6.3E-02	0.0E+00
Phosphoric acid	lb/FU	3.4E-02	3.4E-02	0.0E+00
Hydropotential	m^3-m/FU	4.6E-03	4.6E-03	0.0E+00
Sulfur dioxide	lb/FU	1.6E-03	1.6E-03	0.0E+00
Coal	lb/FU	1.2E-05	1.2E-05	0.0E+00
Residual Fuel Oil	lb/FU	3.2E-06	3.2E-06	0.0E+00
Distillate Fuel Oil	lb/FU	2.8E-07	2.8E-07	0.0E+00
Uranium	lb/FU	2.8E-09	2.8E-09	0.0E+00
Phosphate ore	lb/FU	0.0E+00	0.0E+00	0.0E+00
Proprietary Primer Ingredients	lb/FU	0.0E+00	0.0E+00	0.0E+00
Zinc ore	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Air Emissions</b>				
CO2	lb/FU	2.0E+02	2.0E+02	0.0E+00
SOx	lb/FU	2.1E+01	2.1E+01	0.0E+00
VOC	lb/FU	1.0E+01	1.0E+01	0.0E+00
PM	lb/FU	4.4E+00	4.4E+00	0.0E+00
NOx	lb/FU	4.3E+00	4.3E+00	0.0E+00
Hydrocarbons	lb/FU	2.1E+00	2.1E+00	0.0E+00
CO	lb/FU	5.8E-01	5.8E-01	0.0E+00
Chlorine	lb/FU	4.2E-01	4.2E-01	0.0E+00
PM10	lb/FU	2.9E-01	2.9E-01	0.0E+00
Isobutylaldehyde	lb/FU	2.6E-01	2.6E-01	0.0E+00
Methane	lb/FU	1.8E-01	1.8E-01	0.0E+00
Benzene	lb/FU	1.5E-01	1.5E-01	0.0E+00
Heavy Aromatics	lb/FU	1.4E-01	1.4E-01	0.0E+00
Toluene	lb/FU	8.8E-02	8.8E-02	0.0E+00
Heptane	lb/FU	5.5E-02	5.5E-02	0.0E+00
MIAK	lb/FU	5.1E-02	5.1E-02	0.0E+00
Propane	lb/FU	4.8E-02	4.8E-02	0.0E+00
Hexane	lb/FU	4.3E-02	4.3E-02	0.0E+00
n-Butane	lb/FU	3.8E-02	3.8E-02	0.0E+00
Octane	lb/FU	3.7E-02	3.7E-02	0.0E+00
Acetaldehyde	lb/FU	3.1E-02	3.1E-02	0.0E+00
Xylene	lb/FU	3.1E-02	3.1E-02	0.0E+00
Ethane	lb/FU	3.1E-02	3.1E-02	0.0E+00
Pentane	lb/FU	2.7E-02	2.7E-02	0.0E+00
Butyl alcohol	lb/FU	2.2E-02	0.0E+00	2.2E-02

**Table 6-4. Alternative Primer & Gun CARC System Life Cycle Inventory Summary Results (cont.)**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft^2	1,000		
Aromatic hydrocarbons	lb/FU	2.0E-02	0.0E+00	2.0E-02
Cumene	lb/FU	1.6E-02	1.6E-02	0.0E+00
MEK	lb/FU	1.6E-02	1.6E-02	0.0E+00
Organic Acids	lb/FU	1.6E-02	1.6E-02	0.0E+00
Phenol	lb/FU	1.5E-02	1.5E-02	0.0E+00
Formaldehyde	lb/FU	1.4E-02	1.4E-02	0.0E+00
Aldehydes	lb/FU	1.2E-02	1.2E-02	0.0E+00
C-7 cycloparaffins	lb/FU	7.8E-03	7.8E-03	0.0E+00
Acetone	lb/FU	5.4E-03	5.4E-03	0.0E+00
HCN	lb/FU	4.9E-03	4.9E-03	0.0E+00
Ethylbenzene	lb/FU	3.2E-03	3.2E-03	0.0E+00
C-8 cycloparaffins	lb/FU	2.9E-03	2.9E-03	0.0E+00
Nitroethane	lb/FU	2.0E-03	0.0E+00	2.0E-03
Iso-Butane	lb/FU	1.9E-03	1.9E-03	0.0E+00
Hydrochloric acid	lb/FU	1.4E-03	1.4E-03	0.0E+00
Dichlorodifluoromethane	lb/FU	8.0E-04	8.0E-04	0.0E+00
Ammonia	lb/FU	6.4E-04	6.4E-04	0.0E+00
Naphthalene	lb/FU	4.6E-04	4.6E-04	0.0E+00
2-nitropropane	lb/FU	4.4E-04	4.4E-04	0.0E+00
Ethylene	lb/FU	4.3E-04	4.3E-04	0.0E+00
Acetonitrile	lb/FU	1.7E-05	1.7E-05	0.0E+00
Methanol	lb/FU	1.4E-05	1.4E-05	0.0E+00
Bromotrifluoromethane	lb/FU	6.0E-06	6.0E-06	0.0E+00
Nitric acid	lb/FU	4.0E-06	4.0E-06	0.0E+00
Bromochlorodifluoromethane	lb/FU	1.6E-06	1.6E-06	0.0E+00
1,2-butylene	lb/FU	5.0E-07	5.0E-07	0.0E+00
Kerosene	lb/FU	3.0E-09	3.0E-09	0.0E+00
Lead	lb/FU	6.6E-11	6.6E-11	0.0E+00
Hexyl acetate	lb/FU	0.0E+00	0.0E+00	0.0E+00
Propylene	lb/FU	0.0E+00	0.0E+00	0.0E+00
Sulfuric acid	lb/FU	0.0E+00	0.0E+00	0.0E+00
Ethyl chloride	lb/FU	0.0E+00	0.0E+00	0.0E+00
Vinyl chloride	lb/FU	0.0E+00	0.0E+00	0.0E+00
Isopropyl alcohol	lb/FU	0.0E+00	0.0E+00	0.0E+00
MPK	lb/FU	0.0E+00	0.0E+00	0.0E+00
Propyl acetate	lb/FU	0.0E+00	0.0E+00	0.0E+00
Naphtha	lb/FU	0.0E+00	0.0E+00	0.0E+00
Butyl acetate	lb/FU	0.0E+00	0.0E+00	0.0E+00
Fluorine	lb/FU	0.0E+00	0.0E+00	0.0E+00
MIBK	lb/FU	0.0E+00	0.0E+00	0.0E+00
Trichlorethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Carbon tetrachloride	lb/FU	0.0E+00	0.0E+00	0.0E+00
Chloroform	lb/FU	0.0E+00	0.0E+00	0.0E+00
Butyl cellosolve	lb/FU	0.0E+00	0.0E+00	0.0E+00
Ethylene dichloride	lb/FU	0.0E+00	0.0E+00	0.0E+00
Aliphatic hydrocarbons	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Wastewater Emissions</b>				
Wastewater	lb/FU	2.1E+03	2.1E+03	0.0E+00
WW Reinj'd	lb/FU	1.0E+02	1.0E+02	0.0E+00
WW Discharg.	lb/FU	4.6E+01	4.6E+01	0.0E+00
Mobile ions	lb/FU	2.3E+01	2.3E+01	0.0E+00
WW Injected	lb/FU	1.5E+01	1.5E+01	0.0E+00
Sodium	lb/FU	9.3E+00	9.3E+00	0.0E+00
Chloride	lb/FU	7.4E+00	7.4E+00	0.0E+00
Oil and Grease	lb/FU	2.3E-01	2.3E-01	0.0E+00
Titanium dioxide	lb/FU	1.5E-01	1.5E-01	0.0E+00
Chlorine	lb/FU	8.7E-02	8.7E-02	0.0E+00
Boron	lb/FU	9.8E-03	9.8E-03	0.0E+00
Cadmium	lb/FU	5.7E-03	5.7E-03	0.0E+00
Lead	lb/FU	2.1E-03	2.1E-03	0.0E+00
Aluminum	lb/FU	7.0E-04	7.0E-04	0.0E+00
Chromium	lb/FU	6.4E-04	6.4E-04	0.0E+00
Benzene	lb/FU	4.6E-04	4.6E-04	0.0E+00
Vanadium	lb/FU	1.5E-04	1.5E-04	0.0E+00
Copper	lb/FU	4.9E-05	4.9E-05	0.0E+00

**Table 6-4. Alternative Primer & Gun CARC System Life Cycle Inventory Summary Results (cont.)**

<b>LCI Components</b>	<b>Units</b>	<b>Baseline CARC System Quantity</b>	<b>CARC System Materials Manufacture Quantity</b>	<b>CARC System Use/Reuse Maintenance Quantity</b>
Functional Unit (FU)	ft <sup>2</sup>	1,000		
Zinc	lb/FU	4.9E-05	4.9E-05	0.0E+00
Arsenic	lb/FU	1.9E-05	1.9E-05	0.0E+00
Iron	lb/FU	5.4E-06	5.4E-06	0.0E+00
Mercury	lb/FU	4.2E-06	4.2E-06	0.0E+00
Thallium	lb/FU	3.4E-06	3.4E-06	0.0E+00
Ammonia	lb/FU	1.3E-06	1.3E-06	0.0E+00
Dissolved Solids	lb/FU	4.6E-07	4.6E-07	0.0E+00
Magnesium	lb/FU	1.4E-07	1.4E-07	0.0E+00
Hydrogen cyanide	lb/FU	8.4E-08	8.4E-08	0.0E+00
Sulfuric Acid	lb/FU	6.3E-08	6.3E-08	0.0E+00
COD	lb/FU	3.0E-09	3.0E-09	0.0E+00
Suspended Solids	lb/FU	1.6E-09	1.6E-09	0.0E+00
BOD	lb/FU	9.1E-10	9.1E-10	0.0E+00
Acid	lb/FU	5.0E-10	5.0E-10	0.0E+00
Oil	lb/FU	5.0E-10	5.0E-10	0.0E+00
Metals	lb/FU	2.5E-10	2.5E-10	0.0E+00
Phenol	lb/FU	2.5E-10	2.5E-10	0.0E+00
Sulfide	lb/FU	2.5E-10	2.5E-10	0.0E+00
<b>Solid Wastes</b>				
Hazardous Wastes	lb/FU	7.9E+01	7.0E-01	7.8E+01
Solid Wastes	lb/FU	5.3E+01	5.3E+01	0.0E+00
Acetaldehyde	lb/FU	7.5E-03	7.5E-03	0.0E+00
Methanol	lb/FU	6.6E-03	6.6E-03	0.0E+00
2-nitropropane	lb/FU	5.8E-03	5.8E-03	0.0E+00
Acetone	lb/FU	4.0E-03	4.0E-03	0.0E+00
Acetonitrile	lb/FU	3.3E-03	3.3E-03	0.0E+00
Nitric acid	lb/FU	4.6E-04	4.6E-04	0.0E+00
Ammonia	lb/FU	1.0E-04	1.0E-04	0.0E+00
Formaldehyde	lb/FU	5.7E-05	5.7E-05	0.0E+00
Naphthalene	lb/FU	4.8E-06	4.8E-06	0.0E+00
Hydrogen cyanide	lb/FU	4.8E-06	4.8E-06	0.0E+00
U238	lb/FU	3.6E-09	3.6E-09	0.0E+00
Fly Ash	lb/FU	1.4E-09	1.4E-09	0.0E+00
FGD Solids	lb/FU	5.2E-10	5.2E-10	0.0E+00
Bottom Ash	lb/FU	3.8E-10	3.8E-10	0.0E+00
Slag	lb/FU	1.4E-10	1.4E-10	0.0E+00
U235	lb/FU	3.0E-11	3.0E-11	0.0E+00
Pu (fissile)	lb/FU	2.5E-11	2.5E-11	0.0E+00
Fission Products	lb/FU	1.7E-11	1.7E-11	0.0E+00
Pu (nonfissile)	lb/FU	9.5E-12	9.5E-12	0.0E+00
U236	lb/FU	2.4E-12	2.4E-12	0.0E+00

**Table 6-5. Alternative Thinner CARC System Life Cycle Inventory Summary Results**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft^2	1,000		
<b>Resource and Energy Consumption</b>				
Electricity	BTU/FU	7.7E+05	7.7E+05	0.0E+00
Natural gas	BTU/FU	1.3E+07	1.3E+07	0.0E+00
Steam	BTU/FU	5.5E+05	5.5E+05	0.0E+00
Water	lb/FU	4.0E+04	4.0E+04	0.0E+00
Fuel	lb/FU	3.9E+04	3.9E+04	0.0E+00
Crude oil	lb/FU	2.4E+03	2.4E+03	0.0E+00
Bauxite	lb/FU	8.4E+01	8.4E+01	0.0E+00
Air	lb/FU	7.6E+01	7.6E+01	0.0E+00
Refinery gases	lb/FU	6.8E+01	6.8E+01	0.0E+00
Sodium Chloride	lb/FU	4.3E+01	4.3E+01	0.0E+00
Oxygen	lb/FU	1.4E+01	1.4E+01	0.0E+00
Silica	lb/FU	1.4E+01	1.4E+01	0.0E+00
Chlorine	lb/FU	1.3E+01	1.3E+01	0.0E+00
Zinc ore	lb/FU	8.3E+00	8.3E+00	0.0E+00
Rumenite	lb/FU	6.1E+00	6.1E+00	0.0E+00
Sulfuric acid	lb/FU	6.0E+00	6.0E+00	0.0E+00
Limestone	lb/FU	4.7E+00	4.7E+00	0.0E+00
Chrome oxide	lb/FU	4.6E+00	4.6E+00	0.0E+00
Soda ash	lb/FU	2.6E+00	2.6E+00	0.0E+00
Ilmenite	lb/FU	2.4E+00	2.4E+00	0.0E+00
Magnesium ore	lb/FU	2.2E+00	2.2E+00	0.0E+00
Phosphate ore	lb/FU	2.1E+00	2.1E+00	0.0E+00
Iron ore	lb/FU	1.3E+00	1.3E+00	0.0E+00
Coke	lb/FU	1.1E+00	1.1E+00	0.0E+00
Cobalt oxide	lb/FU	1.0E+00	1.0E+00	0.0E+00
Magnetite	lb/FU	4.0E-01	4.0E-01	0.0E+00
Sodium hydroxide	lb/FU	3.2E-01	3.2E-01	0.0E+00
Coal	lb/FU	2.9E-01	2.9E-01	0.0E+00
Starch	lb/FU	2.1E-01	2.1E-01	0.0E+00
SiAl	lb/FU	5.4E-02	5.4E-02	0.0E+00
Phosphoric acid	lb/FU	4.8E-02	4.8E-02	0.0E+00
Hydrocarbons C8 to C10	lb/FU	1.7E-02	1.7E-02	0.0E+00
Hydropotential	m^3-m/FU	6.3E-03	6.3E-03	0.0E+00
Sulfur dioxide	lb/FU	2.2E-03	2.2E-03	0.0E+00
Residual Fuel Oil	lb/FU	4.5E-06	4.5E-06	0.0E+00
Distillate Fuel Oil	lb/FU	3.9E-07	3.9E-07	0.0E+00
Uranium	lb/FU	3.8E-09	3.8E-09	0.0E+00
Proprietary Primer Ingredients	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Air Emissions</b>				
CO2	lb/FU	2.7E+02	2.7E+02	0.0E+00
SOx	lb/FU	2.1E+01	2.1E+01	0.0E+00
VOC	lb/FU	1.4E+01	1.4E+01	0.0E+00
PM	lb/FU	5.9E+00	5.9E+00	0.0E+00
NOx	lb/FU	5.9E+00	5.9E+00	0.0E+00
Hydrocarbons	lb/FU	3.0E+00	3.0E+00	0.0E+00
CO	lb/FU	1.3E+00	1.3E+00	0.0E+00
Chlorine	lb/FU	5.8E-01	5.8E-01	0.0E+00
MAK	lb/FU	5.2E-01	7.1E-02	4.5E-01
PM10	lb/FU	3.1E-01	3.1E-01	0.0E+00
Methane	lb/FU	2.5E-01	2.5E-01	0.0E+00
Heavy Aromatics	lb/FU	2.0E-01	2.0E-01	0.0E+00
Butyl acetate	lb/FU	1.4E-01	0.0E+00	1.4E-01
Benzene	lb/FU	1.1E-01	1.1E-01	0.0E+00
Heptane	lb/FU	7.6E-02	7.6E-02	0.0E+00
Propane	lb/FU	6.6E-02	6.6E-02	0.0E+00
Naphtha	lb/FU	6.6E-02	0.0E+00	6.6E-02
Hexane	lb/FU	5.9E-02	5.9E-02	0.0E+00
Acetaldehyde	lb/FU	5.4E-02	5.4E-02	0.0E+00
n-Butane	lb/FU	5.3E-02	5.3E-02	0.0E+00
Octane	lb/FU	5.1E-02	5.1E-02	0.0E+00
Xylene	lb/FU	4.7E-02	9.3E-03	3.7E-02
Ethane	lb/FU	4.2E-02	4.2E-02	0.0E+00

**Table 6-5. Alternative Thinner CARC System Life Cycle Inventory Summary Results (continued)**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft <sup>2</sup>	1,000		
Pentane	lb/FU	3.7E-02	3.7E-02	0.0E+00
Butyl alcohol	lb/FU	3.6E-02	0.0E+00	3.6E-02
Fluorine	lb/FU	2.8E-02	2.8E-02	0.0E+00
Cumene	lb/FU	2.7E-02	2.7E-02	0.0E+00
Toluene	lb/FU	2.4E-02	2.2E-02	1.6E-03
MIBK	lb/FU	2.3E-02	1.1E-02	1.2E-02
Aromatic hydrocarbons	lb/FU	2.3E-02	4.0E-04	2.3E-02
Organic Acids	lb/FU	2.2E-02	2.2E-02	0.0E+00
Phenol	lb/FU	2.2E-02	2.2E-02	0.0E+00
Formaldehyde	lb/FU	1.9E-02	1.9E-02	0.0E+00
Aldehydes	lb/FU	1.7E-02	1.7E-02	0.0E+00
C-7 cycloparaffins	lb/FU	1.1E-02	1.1E-02	0.0E+00
Ethylene dichloride	lb/FU	7.7E-03	7.7E-03	0.0E+00
Acetone	lb/FU	7.4E-03	7.4E-03	0.0E+00
HCN	lb/FU	6.7E-03	6.7E-03	0.0E+00
C-8 cycloparaffins	lb/FU	3.9E-03	3.9E-03	0.0E+00
Ethyl chloride	lb/FU	3.0E-03	3.0E-03	0.0E+00
Carbon tetrachloride	lb/FU	2.8E-03	2.8E-03	0.0E+00
Iso-Butane	lb/FU	2.6E-03	2.6E-03	0.0E+00
Ethylene	lb/FU	2.5E-03	2.5E-03	0.0E+00
Trichloroethane	lb/FU	2.3E-03	2.3E-03	0.0E+00
MEK	lb/FU	2.2E-03	7.8E-04	1.5E-03
Isopropyl alcohol	lb/FU	2.1E-03	0.0E+00	2.1E-03
Ethylbenzene	lb/FU	2.1E-03	2.1E-03	0.0E+00
Aliphatic hydrocarbons	lb/FU	1.7E-03	0.0E+00	1.7E-03
Vinyl chloride	lb/FU	1.4E-03	1.4E-03	0.0E+00
Chloroform	lb/FU	1.3E-03	1.3E-03	0.0E+00
Hydrochloric acid	lb/FU	1.3E-03	1.3E-03	0.0E+00
Propylene	lb/FU	1.1E-03	1.1E-03	0.0E+00
Lead	lb/FU	8.8E-04	8.8E-04	0.0E+00
Sulfuric acid	lb/FU	8.3E-05	8.3E-05	0.0E+00
Ammonia	lb/FU	6.2E-06	6.2E-06	0.0E+00
Kerosene	lb/FU	4.1E-09	4.1E-09	0.0E+00
Hexyl acetate	lb/FU	0.0E+00	0.0E+00	0.0E+00
Dichlorodifluoromethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Nitroethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Nitric acid	lb/FU	0.0E+00	0.0E+00	0.0E+00
Naphthalene	lb/FU	0.0E+00	0.0E+00	0.0E+00
Methanol	lb/FU	0.0E+00	0.0E+00	0.0E+00
Bromo-chlorodifluoromethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Bromotrifluoromethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Isobutyaldehyde	lb/FU	0.0E+00	0.0E+00	0.0E+00
Acetonitrile	lb/FU	0.0E+00	0.0E+00	0.0E+00
2-nitropropane	lb/FU	0.0E+00	0.0E+00	0.0E+00
1,2-butylene	lb/FU	0.0E+00	0.0E+00	0.0E+00
Propyl acetate	lb/FU	0.0E+00	0.0E+00	0.0E+00
Butyl cellosolve	lb/FU	0.0E+00	0.0E+00	0.0E+00
MPK	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Wastewater Emissions</b>				
Wastewater	lb/FU	3.0E+03	3.0E+03	0.0E+00
WW Reinj'd	lb/FU	1.4E+02	1.4E+02	0.0E+00
WW Discharg.	lb/FU	6.4E+01	6.4E+01	0.0E+00
Mobile ions	lb/FU	3.1E+01	3.1E+01	0.0E+00
WW Injected	lb/FU	2.1E+01	2.1E+01	0.0E+00
Sodium	lb/FU	1.3E+01	1.3E+01	0.0E+00
Chloride	lb/FU	1.0E+01	1.0E+01	0.0E+00
Oil and Grease	lb/FU	3.2E-01	3.2E-01	0.0E+00
Titanium dioxide	lb/FU	1.3E-01	1.3E-01	0.0E+00
Chlorine	lb/FU	3.9E-02	3.9E-02	0.0E+00
Boron	lb/FU	1.3E-02	1.3E-02	0.0E+00
Cadmium	lb/FU	4.9E-03	4.9E-03	0.0E+00
Lead	lb/FU	1.8E-03	1.8E-03	0.0E+00
Benzene	lb/FU	6.3E-04	6.3E-04	0.0E+00

**Table 6-5. Alternative Thinner CARC System Life Cycle Inventory Summary Results (continued)**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft <sup>2</sup>	1,000		
Aluminum	lb/FU	5.9E-04	5.9E-04	0.0E+00
Chromium	lb/FU	5.5E-04	5.5E-04	0.0E+00
Vanadium	lb/FU	1.3E-04	1.3E-04	0.0E+00
Copper	lb/FU	4.1E-05	4.1E-05	0.0E+00
Zinc	lb/FU	4.1E-05	4.1E-05	0.0E+00
Arsenic	lb/FU	2.6E-05	2.6E-05	0.0E+00
Iron	lb/FU	7.4E-06	7.4E-06	0.0E+00
Mercury	lb/FU	5.5E-06	5.5E-06	0.0E+00
Thallium	lb/FU	4.7E-06	4.7E-06	0.0E+00
Dissolved Solids	lb/FU	6.3E-07	6.3E-07	0.0E+00
Magnesium	lb/FU	1.2E-07	1.2E-07	0.0E+00
Sulfuric Acid	lb/FU	8.7E-08	8.7E-08	0.0E+00
COD	lb/FU	4.2E-09	4.2E-09	0.0E+00
Suspended Solids	lb/FU	2.2E-09	2.2E-09	0.0E+00
BOD	lb/FU	1.3E-09	1.3E-09	0.0E+00
Acid	lb/FU	7.0E-10	7.0E-10	0.0E+00
Oil	lb/FU	7.0E-10	7.0E-10	0.0E+00
Metals	lb/FU	3.5E-10	3.5E-10	0.0E+00
Phenol	lb/FU	3.5E-10	3.5E-10	0.0E+00
Sulfide	lb/FU	3.5E-10	3.5E-10	0.0E+00
Ammonia	lb/FU	0.0E+00	0.0E+00	0.0E+00
Hydrogen cyanide	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Solid Wastes</b>				
Hazardous Wastes	lb/FU	8.1E+01	2.3E+00	7.8E+01
Solid Wastes	lb/FU	6.2E+01	6.2E+01	0.0E+00
U238	lb/FU	5.0E-09	5.0E-09	0.0E+00
Fly Ash	lb/FU	1.9E-09	1.9E-09	0.0E+00
FGD Solids	lb/FU	7.2E-10	7.2E-10	0.0E+00
Bottom Ash	lb/FU	5.3E-10	5.3E-10	0.0E+00
Slag	lb/FU	2.0E-10	2.0E-10	0.0E+00
U235	lb/FU	4.2E-11	4.2E-11	0.0E+00
Pu (fissile)	lb/FU	3.4E-11	3.4E-11	0.0E+00
Fission Products	lb/FU	2.4E-11	2.4E-11	0.0E+00
Pu (nonfissile)	lb/FU	1.3E-11	1.3E-11	0.0E+00
U236	lb/FU	3.3E-12	3.3E-12	0.0E+00
Methanol	lb/FU	0.0E+00	0.0E+00	0.0E+00
Ammonia	lb/FU	0.0E+00	0.0E+00	0.0E+00
Nitric acid	lb/FU	0.0E+00	0.0E+00	0.0E+00
Naphthalene	lb/FU	0.0E+00	0.0E+00	0.0E+00
Formaldehyde	lb/FU	0.0E+00	0.0E+00	0.0E+00
2-nitropropane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Acetonitrile	lb/FU	0.0E+00	0.0E+00	0.0E+00
Acetone	lb/FU	0.0E+00	0.0E+00	0.0E+00
Acetaldehyde	lb/FU	0.0E+00	0.0E+00	0.0E+00
Hydrogen cyanide	lb/FU	0.0E+00	0.0E+00	0.0E+00

The fifth and final alternative utilized both an alternative thinner and alternative primer combined with the baseline gun (Table 6-6). As expected, the combined alternatives showed reduced resource and energy consumption in many areas including electricity, natural gas, steam, water, crude oil, air, and refinery gases. Increases were seen in fuel, sodium chloride, chlorine, rumenite, ilmenite mainly from the TiO<sub>2</sub> production stages. Major air emissions categories showed the expected reductions in CO<sub>2</sub>, VOC, PM, NO<sub>x</sub>, hydrocarbons, and CO. Slight increases were noted in minor organic chemical releases. Water usage and emissions were generally reduced, but increases were noted in the heavy metal content. Solid wastes were generally reduced with the exception of those from the nitroethane production processes.

The comparison of energy usage across the alternatives in comparison with the baseline is shown in Figure 6-1. This again illustrates the preferability of Alternative 2 (turbine HVLP gun) and Alternative 3 (gun plus primer substitution). A consistent reinforcement of this is observed in the solid/hazardous waste (Figure 6-2) and air pollutant (Figure 6-3) graphs as well.

## 6.2 Environmental Impact/Hazard Characterization

### 6.2.1 *Impact Characterization*

The environmental impact significance of the resource and emission data from the baseline and each alternative CARC LCI was characterized (evaluated) using the same set of equivalency factors derived during the baseline analysis (see Table 4-2). The importance of each individual resource or chemical within an impact category was determined by multiplying the equivalency factor times the inventory value in pounds per functional unit. The results of these calculations for each resource or emission are provided as "factored scores" within each of the nine impact categories in Appendix D. These "factored scores" are the basis for the environmental impact valuation results, which combine the results for the economic and performance assessments and the values from the AHP weighting factors in arriving at the conclusions regarding the best improvement opportunity.

The potential environmental impacts associated with each of the alternatives can be evaluated by comparing the normalized, factored, impact scores for each of the nine major impact categories (Table 6-7). As indicated by the bold scores in Table 6-7, the CARC system with the most (7 out of 9) low scores (least potential impacts) in each impact category is the option with both the alternative primer (water-thinned) and alternative spray gun (turbine). Use of the alternative gun decreases the use rates of topcoat, primer, and thinner, which reduces the potential environmental impact in all nine of the impact categories compared to the baseline.

**Table 6-6. Alternative Primer and Thinner CARC System Life Cycle Inventory Summary Results**

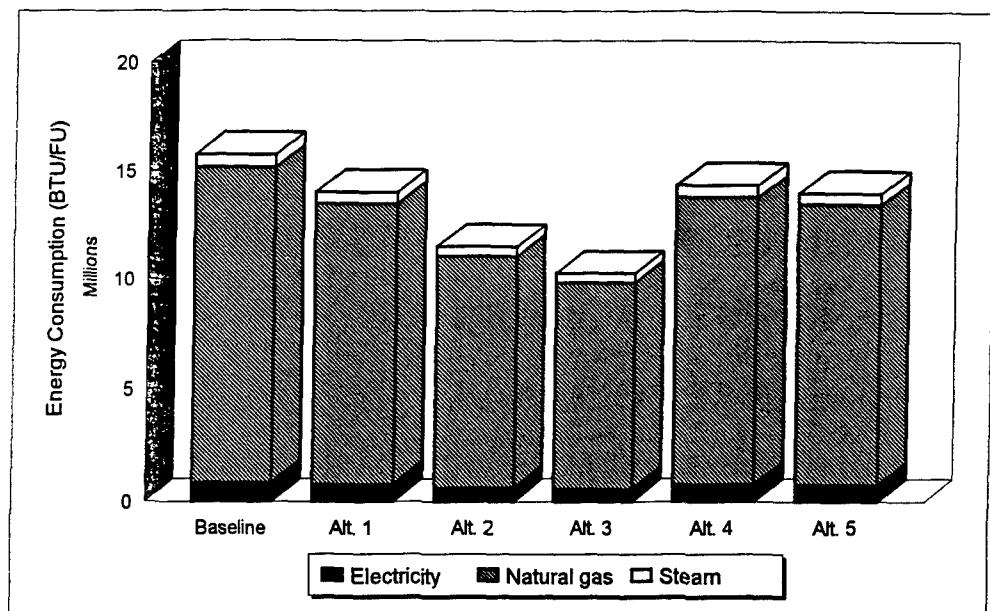
LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft <sup>2</sup>	1,000		
<b>Resource and Energy Consumption</b>				
Electricity	BTU/FU	7.7E+05	7.4E+05	3.1E+04
Natural gas	BTU/FU	1.3E+07	1.3E+07	3.5E-03
Steam	BTU/FU	5.0E+05	5.0E+05	4.1E+03
Fuel	lb/FU	6.4E+04	6.4E+04	0.0E+00
Water	lb/FU	4.1E+04	4.1E+04	0.0E+00
Crude oil	lb/FU	2.6E+03	2.3E+03	2.6E+02
Air	lb/FU	1.2E+02	1.2E+02	0.0E+00
Bauxite	lb/FU	8.4E+01	8.4E+01	0.0E+00
Refinery gases	lb/FU	6.4E+01	6.4E+01	0.0E+00
Sodium Chloride	lb/FU	4.3E+01	4.3E+01	0.0E+00
Chlorine	lb/FU	1.5E+01	1.5E+01	0.0E+00
Silica	lb/FU	1.3E+01	1.3E+01	0.0E+00
Oxygen	lb/FU	1.2E+01	1.2E+01	0.0E+00
Rumenite	lb/FU	9.9E+00	9.9E+00	0.0E+00
Sulfuric acid	lb/FU	8.2E+00	8.2E+00	0.0E+00
Limestone	lb/FU	4.7E+00	4.7E+00	0.0E+00
Chrome oxide	lb/FU	4.6E+00	4.6E+00	0.0E+00
Ilmenite	lb/FU	3.9E+00	3.9E+00	0.0E+00
Soda ash	lb/FU	2.6E+00	2.6E+00	0.0E+00
Magnesium ore	lb/FU	2.2E+00	2.2E+00	0.0E+00
Coke	lb/FU	1.8E+00	1.8E+00	0.0E+00
Iron ore	lb/FU	1.3E+00	1.3E+00	0.0E+00
Cobalt oxide	lb/FU	1.0E+00	1.0E+00	0.0E+00
Sodium hydroxide	lb/FU	5.3E-01	5.3E-01	0.0E+00
Magnetite	lb/FU	4.0E-01	4.0E-01	0.0E+00
Starch	lb/FU	2.1E-01	2.1E-01	0.0E+00
SiAl	lb/FU	8.8E-02	8.8E-02	0.0E+00
Phosphoric acid	lb/FU	4.8E-02	4.8E-02	0.0E+00
Hydrocarbons C8 to C10	lb/FU	1.7E-02	1.7E-02	0.0E+00
Hydropotential	m <sup>3</sup> -m/FU	6.4E-03	6.1E-03	2.5E-04
Sulfur dioxide	lb/FU	2.2E-03	2.2E-03	0.0E+00
Coal	lb/FU	1.6E-05	1.5E-05	0.0E+00
Residual Fuel Oil	lb/FU	4.5E-06	4.3E-06	0.0E+00
Distillate Fuel Oil	lb/FU	3.9E-07	3.8E-07	0.0E+00
Uranium	lb/FU	3.8E-09	3.7E-09	0.0E+00
Phosphate ore	lb/FU	0.0E+00	0.0E+00	0.0E+00
Proprietary Primer Ingredients	lb/FU	0.0E+00	0.0E+00	0.0E+00
Zinc ore	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Air Emissions</b>				
CO2	lb/FU	2.9E+02	2.6E+02	2.7E+01
SOx	lb/FU	2.1E+01	2.1E+01	3.2E-02
VOC	lb/FU	1.3E+01	1.3E+01	0.0E+00
NOx	lb/FU	6.0E+00	5.8E+00	1.9E-01
PM	lb/FU	6.0E+00	6.0E+00	0.0E+00
Hydrocarbons	lb/FU	3.1E+00	2.8E+00	3.1E-01
CO	lb/FU	8.3E-01	7.6E-01	7.0E-02
Chlorine	lb/FU	5.9E-01	5.9E-01	0.0E+00
MAK	lb/FU	5.2E-01	7.1E-02	4.5E-01
PM10	lb/FU	3.1E-01	3.1E-01	0.0E+00
Benzene	lb/FU	2.7E-01	2.7E-01	0.0E+00
Methane	lb/FU	2.6E-01	2.3E-01	2.6E-02
Heavy Aromatics	lb/FU	2.0E-01	2.0E-01	0.0E+00
Toluene	lb/FU	1.9E-01	1.9E-01	1.4E-03
Heptane	lb/FU	8.1E-02	7.3E-02	8.0E-03
Propane	lb/FU	7.0E-02	6.3E-02	6.9E-03
Naphtha	lb/FU	6.6E-02	0.0E+00	6.6E-02
Hexane	lb/FU	6.3E-02	5.7E-02	6.2E-03
Aromatic hydrocarbons	lb/FU	6.1E-02	0.0E+00	6.1E-02
n-Butane	lb/FU	5.6E-02	5.0E-02	5.5E-03
Octane	lb/FU	5.4E-02	4.9E-02	5.3E-03
Xylene	lb/FU	4.7E-02	8.9E-03	3.8E-02
Ethane	lb/FU	4.5E-02	4.0E-02	4.4E-03

**Table 6-6. Alternative Primer and Thinner CARC System Life Cycle Inventory Summary Results  
(cont.)**

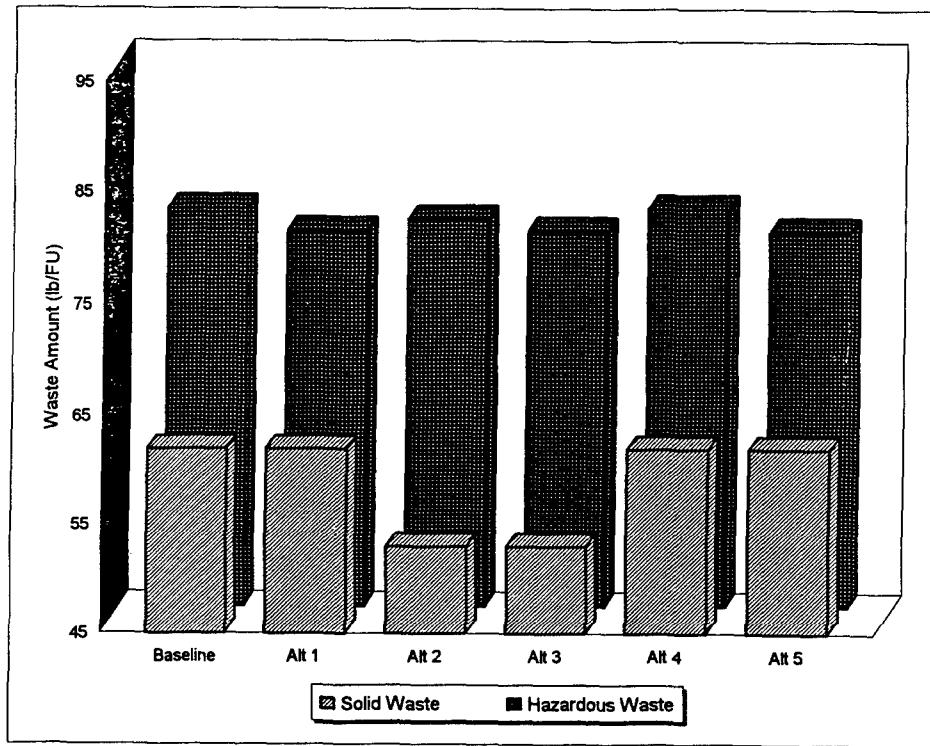
LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft <sup>2</sup>	1,000		
Butyl alcohol	lb/FU	4.2E-02	0.0E+00	4.2E-02
Pentane	lb/FU	3.9E-02	3.5E-02	3.9E-03
Butyl acetate	lb/FU	2.4E-02	0.0E+00	2.4E-02
Organic Acids	lb/FU	2.3E-02	2.1E-02	2.3E-03
Cumene	lb/FU	2.3E-02	2.3E-02	0.0E+00
Phenol	lb/FU	2.1E-02	2.1E-02	0.0E+00
Formaldehyde	lb/FU	2.0E-02	1.8E-02	1.9E-03
Aldehydes	lb/FU	1.8E-02	1.6E-02	1.8E-03
C-7 cycloparaffins	lb/FU	1.1E-02	1.0E-02	1.1E-03
Acetone	lb/FU	7.9E-03	7.1E-03	7.7E-04
HCN	lb/FU	6.8E-03	6.8E-03	0.0E+00
Acetaldehyde	lb/FU	6.2E-03	6.2E-03	0.0E+00
Hexyl acetate	lb/FU	5.5E-03	0.0E+00	5.5E-03
MEK	lb/FU	4.5E-03	7.8E-04	3.7E-03
C-8 cycloparaffins	lb/FU	4.2E-03	3.8E-03	4.1E-04
Nitroethane	lb/FU	3.9E-03	0.0E+00	3.9E-03
Iso-Butane	lb/FU	2.8E-03	2.5E-03	2.7E-04
Hydrochloric acid	lb/FU	1.9E-03	1.9E-03	0.0E+00
Ethylbenzene	lb/FU	1.8E-03	1.8E-03	0.0E+00
Propylene	lb/FU	1.1E-03	1.1E-03	0.0E+00
Dichlorodifluoromethane	lb/FU	1.1E-03	1.1E-03	0.0E+00
Ammonia	lb/FU	8.9E-04	8.9E-04	0.0E+00
Naphthalene	lb/FU	6.4E-04	6.4E-04	0.0E+00
2-nitropropane	lb/FU	6.1E-04	6.1E-04	0.0E+00
Ethylene	lb/FU	2.9E-04	2.9E-04	0.0E+00
Sulfuric acid	lb/FU	8.3E-05	8.3E-05	0.0E+00
Acetonitrile	lb/FU	2.4E-05	2.4E-05	0.0E+00
Methanol	lb/FU	1.9E-05	1.9E-05	0.0E+00
Bromotrifluoromethane	lb/FU	8.3E-06	8.3E-06	0.0E+00
Nitric acid	lb/FU	5.5E-06	5.5E-06	0.0E+00
Bromochlorodifluoromethane	lb/FU	2.2E-06	2.2E-06	0.0E+00
1,2-butylene	lb/FU	7.0E-07	7.0E-07	0.0E+00
Kerosene	lb/FU	4.1E-09	3.9E-09	0.0E+00
Lead	lb/FU	9.2E-11	8.8E-11	0.0E+00
Ethyl chloride	lb/FU	0.0E+00	0.0E+00	0.0E+00
Vinyl chloride	lb/FU	0.0E+00	0.0E+00	0.0E+00
Fluorine	lb/FU	0.0E+00	0.0E+00	0.0E+00
MPK	lb/FU	0.0E+00	0.0E+00	0.0E+00
Propyl acetate	lb/FU	0.0E+00	0.0E+00	0.0E+00
Isopropyl alcohol	lb/FU	0.0E+00	0.0E+00	0.0E+00
MIBK	lb/FU	0.0E+00	0.0E+00	0.0E+00
Isobutylraldehyde	lb/FU	0.0E+00	0.0E+00	0.0E+00
Trichloroethane	lb/FU	0.0E+00	0.0E+00	0.0E+00
Carbon tetrachloride	lb/FU	0.0E+00	0.0E+00	0.0E+00
Chloroform	lb/FU	0.0E+00	0.0E+00	0.0E+00
Butyl cellosolve	lb/FU	0.0E+00	0.0E+00	0.0E+00
Ethylene dichloride	lb/FU	0.0E+00	0.0E+00	0.0E+00
Aliphatic hydrocarbons	lb/FU	0.0E+00	0.0E+00	0.0E+00
<b>Wastewater Emissions</b>				
Wastewater	lb/FU	3.0E+03	3.0E+03	0.0E+00
WW Reinj'd	lb/FU	1.5E+02	1.4E+02	1.5E+01
WW Discharg.	lb/FU	6.7E+01	6.1E+01	6.6E+00
Mobile ions	lb/FU	3.3E+01	3.0E+01	3.2E+00
WW Injected	lb/FU	2.2E+01	2.0E+01	2.2E+00
Sodium	lb/FU	1.4E+01	1.2E+01	1.3E+00
Chloride	lb/FU	1.1E+01	9.7E+00	1.1E+00
Oil and Grease	lb/FU	3.3E-01	3.0E-01	3.3E-02
Titanium dioxide	lb/FU	2.1E-01	2.1E-01	0.0E+00
Chlorine	lb/FU	1.2E-01	1.2E-01	0.0E+00
Boron	lb/FU	1.4E-02	1.3E-02	1.4E-03
Cadmium	lb/FU	8.0E-03	8.0E-03	0.0E+00
Lead	lb/FU	2.9E-03	2.9E-03	0.0E+00
Aluminum	lb/FU	9.7E-04	9.7E-04	0.0E+00

**Table 6-6. Alternative Primer and Thinner CARC System Life Cycle Inventory Summary Results  
(cont.)**

LCI Components	Units	Baseline CARC System Quantity	CARC System Materials Manufacture Quantity	CARC System Use/Reuse Maintenance Quantity
Functional Unit (FU)	ft <sup>2</sup>	1,000		
Chromium	lb/FU	8.9E-04	8.9E-04	0.0E+00
Benzene	lb/FU	6.7E-04	6.1E-04	0.0E+00
Vanadium	lb/FU	2.1E-04	2.1E-04	0.0E+00
Copper	lb/FU	6.8E-05	6.8E-05	0.0E+00
Zinc	lb/FU	6.8E-05	6.8E-05	0.0E+00
Arsenic	lb/FU	2.8E-05	2.5E-05	0.0E+00
Iron	lb/FU	7.5E-06	7.2E-06	0.0E+00
Mercury	lb/FU	6.1E-06	5.6E-06	0.0E+00
Thallium	lb/FU	4.9E-06	4.4E-06	0.0E+00
Ammonia	lb/FU	1.7E-06	1.7E-06	0.0E+00
Dissolved Solids	lb/FU	6.3E-07	6.1E-07	0.0E+00
Magnesium	lb/FU	1.9E-07	1.9E-07	0.0E+00
Hydrogen cyanide	lb/FU	1.2E-07	1.2E-07	0.0E+00
Sulfuric Acid	lb/FU	8.7E-08	8.4E-08	0.0E+00
COD	lb/FU	4.2E-09	4.0E-09	0.0E+00
Suspended Solids	lb/FU	2.2E-09	2.1E-09	0.0E+00
BOD	lb/FU	1.3E-09	1.2E-09	0.0E+00
Oil	lb/FU	7.0E-10	6.7E-10	0.0E+00
Acid	lb/FU	7.0E-10	6.7E-10	0.0E+00
Metals	lb/FU	3.5E-10	3.4E-10	0.0E+00
Sulfide	lb/FU	3.5E-10	3.4E-10	0.0E+00
Phenol	lb/FU	3.5E-10	3.4E-10	0.0E+00
<b>Solid Wastes</b>				
Hazardous Wastes	lb/FU	7.9E+01	9.8E-01	7.8E+01
Solid Wastes	lb/FU	6.2E+01	6.2E+01	0.0E+00
Acetaldehyde	lb/FU	1.0E-02	1.0E-02	0.0E+00
Methanol	lb/FU	9.2E-03	9.2E-03	0.0E+00
2-nitropropane	lb/FU	8.1E-03	8.1E-03	0.0E+00
Acetone	lb/FU	5.6E-03	5.6E-03	0.0E+00
Acetonitrile	lb/FU	4.6E-03	4.6E-03	0.0E+00
Nitric acid	lb/FU	6.4E-04	6.4E-04	0.0E+00
Ammonia	lb/FU	1.4E-04	1.4E-04	0.0E+00
Formaldehyde	lb/FU	8.0E-05	8.0E-05	0.0E+00
Naphthalene	lb/FU	6.6E-06	6.6E-06	0.0E+00
Hydrogen cyanide	lb/FU	6.6E-06	6.6E-06	0.0E+00
U238	lb/FU	4.8E-09	4.8E-09	0.0E+00
Fly Ash	lb/FU	1.8E-09	1.8E-09	0.0E+00
FGD Solids	lb/FU	7.0E-10	7.0E-10	0.0E+00
Bottom Ash	lb/FU	5.1E-10	5.1E-10	0.0E+00
Slag	lb/FU	1.9E-10	1.9E-10	0.0E+00
U235	lb/FU	4.0E-11	4.0E-11	0.0E+00
Pu (fissile)	lb/FU	3.3E-11	3.3E-11	0.0E+00
Fission Products	lb/FU	2.3E-11	2.3E-11	0.0E+00
Pu (nonfissile)	lb/FU	1.3E-11	1.3E-11	0.0E+00
U236	lb/FU	3.2E-12	3.2E-12	0.0E+00



**Figure 6-1. Energy consumption by type.**



**Figure 6-2. Solid/hazardous waste.**

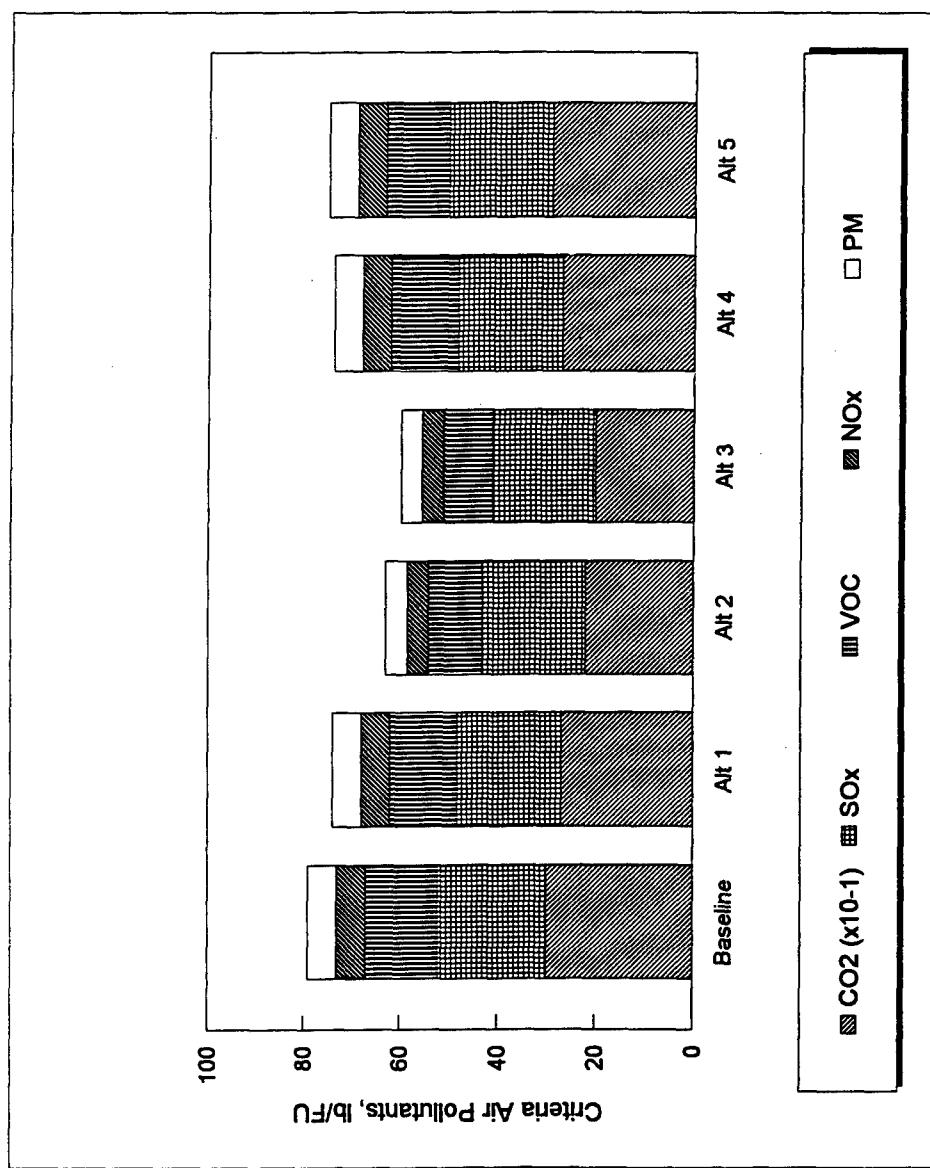


Figure 6-3. Criteria air pollutants

**Table 6-7. Comparison of Normalized, Factored Environmental Impact Scores for the Baseline and Alternative CARC Systems**

		IMPACT SCORES FOR CARC SYSTEMS (best scores for each impact category in bold)					
Spatial Scale	Impact Categories**	BASELINE	ALTERNATIVE PRIMER	ALTERNATIVE GUN	ALTERNATIVE & THINNER	ALTERNATIVE GUN	ALTERNATIVE PRIMER & THINNER
<b>GLOBAL</b>							
	ODP	1.090	<b>0.367</b>	<b>0.799</b>	<b>0.265</b>	1.106	<b>0.367</b>
	GLBLWRM	1.013	<b>0.927</b>	<b>0.739</b>	<b>0.677</b>	0.905	<b>0.984</b>
	FSLFUELS	1.263	<b>1.121</b>	<b>0.929</b>	<b>0.827</b>	1.133	<b>1.180</b>
<b>REGIONAL</b>							
	ACIDDEP	1.198	<b>1.173</b>	<b>1.116</b>	<b>1.098</b>	1.187	<b>1.175</b>
	SMOG	1.114	<b>0.993</b>	<b>0.800</b>	<b>0.721</b>	1.035	<b>0.992</b>
	WTRUSE						
<b>LOCAL</b>							
	<b>TOXICITY</b>		HUMAN	2.150	<b>1.612</b>	<b>1.510</b>	<b>1.172</b>
	ENVTER	<b>3.799</b>		<b>2.635</b>	<b>2.565</b>	<b>1.906</b>	<b>1.999</b>
	ENVAQ	<b>1.280</b>		<b>3.537</b>	<b>0.929</b>	<b>2.554</b>	<b>2.923</b>
	LANDUSE	<b>1.577</b>		<b>1.585</b>	<b>1.493</b>	<b>1.497</b>	<b>1.279</b>

\* The normalized factored score for an impact category equals the sum for each chemical of the product of inventory quantity times equivalency factor.

\*\* ODP = Ozone Depletion Potential, GLBLWRM = Global Warming Potential, FSLFUELS = Fossil Fuel & Mineral Depletion Potential  
 ACIDDEP = Acid Deposition Potential, SMOG = Smog Creation Potential, WTRUSE = Water Use, HUMAN = Human Health Toxicity  
 Potential, ENVTER = Terrestrial Wildlife Toxicity Potential, ENVAQ = Aquatic Biota Toxicity Potential, LANDUSE = Land Use  
 for Waste Disposal

The scores for all three of the global scale impact categories were lowest in the option involving the alternative primer and spray gun. The normalized, factored, impact scores for ozone depletion potential suggest that this impact category is reduced by using the alternative primer and spray gun, which is the result of a reduction in the emission of carbon tetrachloride and trichloroethane during manufacture of ingredients for the alternative versus baseline primers. However, the ozone depletion impact from the baseline primer is expected to be eliminated in the near future as the manufacturer eliminates trichloroethane, which is used during manufacture. The normalized, factored, impact scores for global warming potential suggest that this impact category is reduced by using the alternative primer and spray gun, which is the result of a reduction in the emission of carbon tetrachloride, CO<sub>2</sub>, and trichloroethane during manufacture of ingredients for the alternative versus baseline primer. There is also a reduction in the normalized, factored, impact score for natural resource use (e.g. fossil fuels, phosphate rock, and zinc) with use of the alternative primer and spray gun, associated with the decreased manufacture of intermediate materials.

The scores for the two relevant regional scale impact categories were lowest in the option involving the alternative primer and spray gun. There is a decrease in the normalized, factored, impact score for acid deposition potential with use of the alternative primer & gun, mainly due to a decrease in all acid deposition precursor emissions, resulting from decreased use rates of topcoat, primer, and thinner. There is also a decrease in the smog creation potential score with the use of the alternative primer and spray gun, mainly due to a decrease in release of total VOC emissions (chemical species not available) during manufacture of ingredients for the alternative versus baseline primer, as well as decreased use rates of topcoat, primer, and thinner associated with use of the alternative spray gun.

Of the three toxicity impact categories considered, human health and terrestrial wildlife toxicity impact potentials showed the greatest reduction for the option involving the alternative primer and spray gun. Aquatic biota toxicity, however, was lowest with the option involving the baseline primer and alternative spray gun. There is a decrease in the normalized, factored, impact score for human toxicity potential associated with the manufacture of intermediate materials for the alternative versus baseline primer, which is the result of a reduction in the emission of several toxic materials (e.g., acetaldehyde, n-butane, n-butyl acetate, chlorine, CO, ethylene dichloride, fluorine, isobutyraldehyde, MIAK, MIBK, and n-pentane) during manufacture of ingredients for the alternative primer or during drying of the primer after application. There is a decrease in the normalized, factored, impact score for terrestrial wildlife toxicity potential associated with the manufacture of intermediate materials for the alternative versus baseline primer, which is the result of a reduction in the emission of several toxic materials (e.g., n-heptane, isobutyraldehyde, and MIAK) during manufacture of ingredients for the alternative primer or during drying of the primer after application. Use of the alternative primer, even with the alternative gun, is worse than the baseline in the aquatic toxicity impact area. This is due to the increase in cadmium and chlorine in the wastewater associated with manufacture of the ingredients for the alternative primer. However, use of the alternative gun with the baseline primer gives the lowest potential impact score for aquatic biota.

The local scale impact of land use resulting from waste disposal shows the greatest reduction in potential impact score for two alternatives: the alternative gun and the alternative gun with alternative primer. This is associated with a reduction in the quantity of hazardous and nonhazardous waste from manufacturing of different ingredients for the alternative primer and from decreased use rates of topcoat, primer, and thinner resulting from use of the alternative spray gun.

### **6.2.2 Sensitivity Analysis**

One of the considerations in conducting an LCA is the integration of the understanding of the uncertainties in the information with the results. In this case the uncertainties in the inventory data were overlaid with the possible uncertainties introduced in the impact assessment. To assess the

possible consequences, if any, on the results of having missing or incorrect equivalency factors, a sensitivity analysis was performed. In this analysis, the details of which are provided in Appendix E, two value substitutions were made for the equivalency factors. One situation occurred where the baseline CARC system contained a specific chemical species, for example toluene, and the alternative formulation simply identified a chemical category, for example aromatic hydrocarbons. To test the effect of this on the impact scores, a worst case scenario consisting of selecting the most adverse equivalency factor appropriate to the impact category (ozone depletion, global warming, toxicity, etc.) was chosen and the modeling calculations repeated. The resulting values were then compared to the "expected" value and a percentage difference computed. Although large differences in any one environmental category could occur if this scenario were true, the overall environmental impact scores varied by an average of 5.4% with a range from 3.2% for Alternative 4 (alternative thinner) to 8.6% for Alternative 5 (alternative thinner and primer). Thus, the analyzed results are considered to be acceptable to within about 5 to 6% when the effect of factor specificity is concerned.

A second type of uncertainty arises if an equivalency factor is known for one component of the baseline system and completely unknown for a substitute. In this case the alternative could be favored simply because more adverse impacts were loading onto the baseline system. This situation did not occur for any constituents considered to contribute in significant mass quantities to the overall impact, but should be kept in mind in applying the valuation procedure in general.

A third type of uncertainty exists that was not evaluated directly. This uncertainty pertains to the variability in the equivalency factor themselves. For example, the basis for global warming equivalencies is the modeling of climatological effects of insertion of a known amount of a global warming gas into the atmosphere. The impact potential is followed by tracking its chemistry through time and integrating the incremental effect over periods of 20 to 500 years. Uncertainty exists in the models and the understanding of the basic chemistry. The overall magnitude of the uncertainties have been estimated by the international or regional bodies responsible for creating the equivalency factors. In a comparative analysis of this type the uncertainties would be expected to affect both the baseline and alternatives.

### **6.3 Economic Assessment**

The estimated costs for CARC depainting and painting are summarized in Table 6-8. Fort Eustis costs are represented by the baseline cost. Costs for five alternative systems are also presented.

#### ***6.3.1 Fixed Capital Investment***

The estimated baseline FCI, \$516,000, was based on operations at Fort Eustis. A breakdown of the estimated FCI costs for CARC depainting and painting is shown in Table 6-9. Fort Eustis costs are represented by the baseline cost. Costs for five alternative systems are also presented.

**Table 6-8. Estimated FCI, Annual Operating Cost, and Annualized Costs**

	Baseline	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Fixed Capital Investment (FCI), \$1000	516	516	548	548	516	516
Annual operating cost						
\$1000/yr	1,797	1,788	1,574	1,565	1,797	1,787
\$/1000 ft <sup>2</sup>	2,903	2,888	2,542	2,928	2,901	2,885
Annualized cost						
\$1000/yr	1,845	1,837	1,625	1,616	1,845	1,835
\$/1000 ft <sup>2</sup>	2,981	2,966	2,625	2,611	2,979	2,963

### **6.3.2 Annual Operating Cost**

The estimated annual baseline operating cost, based on operations typical of Fort Eustis, is \$1,797,000/yr. Details for the basecase and the five alternative systems are shown in Table 6-10.

### **6.3.3 Annualized Cost**

The estimated baseline annualized cost, \$1,797,000/yr, is the sum of the annual operating cost and amortization at Ft. Eustis. Annualized cost for the baseline case and five alternative systems are summarized in Table 6-11.

**Table 6-9. Estimated Baseline Fixed Capital Investment**

Cost Item	Baseline	Alt. 2	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Basis <sup>(a)</sup>
Purchased equipment	120,500	120,500	130,000	130,000	120,500	120,500	100% of PE
PE installation	54,225	54,225	58,500	58,500	54,225	54,225	45% of PE cost
Instrument and control	10,845	10,845	11,700	11,700	10,845	10,845	9% of PE cost
Piping	19,280	19,280	20,800	20,800	19,280	19,280	15% of PE cost
Electrical	12,050	12,050	13,000	13,000	12,050	12,050	10% of PE cost
Building	102,000	102,000	102,000	102,000	102,000	102,000	\$43 per sq ft
Yard improvement	15,665	15,665	16,900	16,900	15,665	15,665	13% of PE cost
Service facilities	48,200	48,200	52,000	52,000	48,200	48,200	40% of PE cost
Land	0	0	0	0	0	0	
<b>Total Direct Plant Cost</b>	<b>382,765</b>	<b>382,765</b>	<b>404,900</b>	<b>404,900</b>	<b>382,765</b>	<b>382,765</b>	
Engineering and	39,765	39,765	42,900	42,900	39,765	39,765	33% of PE cost
Construction expense	46,995	46,995	50,700	50,700	46,995	46,995	39% of PE cost
<b>Total Direct and Indirect</b>	<b>469,525</b>	<b>469,525</b>	<b>498,500</b>	<b>498,500</b>	<b>469,525</b>	<b>469,525</b>	
Contractors fees	23,476	23,476	24,925	24,925	23,476	23,476	5% of direct
Contingency	23,476	23,476	24,925	24,925	23,476	23,476	5% of direct
<b>Fixed Capital</b>	<b>516,478</b>	<b>516,478</b>	<b>548,350</b>	<b>548,350</b>	<b>516,478</b>	<b>516,478</b>	

(a) Peters and Timmerhaus, 1991

**Table 6-10. Estimated Annual Operating Cost**

Cost Item	Baseline	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Basis
<b>Raw Materials</b>							
Basecase topcoat	111,456	111,456	81,586	81,586	111,456	111,456	\$36/gal <sup>(a)</sup>
Basecase primer	26,316	0.00	26,316	0.00	26,316	0.00	\$17/gal <sup>(a)</sup>
Alternative primer	0.00	22,727	0.00	22,727	0.00	22,727	\$20.33/gal <sup>(a)</sup>
Basecase thinner	15,093	15,093	15,093	15,093	0.00	0.00	\$15/gal <sup>(a)</sup>
Alternative thinner	0.00	0.00	0.00	0.00	15,093	15,093	\$15/gal <sup>(a)</sup>
Depainting grit	7,992	7,992	7,992	7,992	7,992	7,992	\$0.25/lb <sup>(a)</sup>
<b>Utility</b>							
Electricity	1,053	1,053	1,053	807	807	1,053	\$0.06/kWhr
<b>Labor</b>							
Operating	683,700	682,410	597,700	596,410	683,700	682,410	\$25/hr <sup>(b)</sup>
Maintenance	15,493	15,493	16,451	16,451	15,493	15,493	3% of FCI <sup>(c)</sup>
Supervision	102,555	102,363	89,655	89,462	102,555	102,362	15% of operating labor <sup>(c)</sup>
Operating Supplies	102,555	102,363	89,655	89,462	102,555	102,362	15% of operating labor <sup>(c)</sup>
Maintenance Supplies	20,657	20,657	20,657	20,657	20,657	20,657	4% of FCI <sup>(c)</sup>
Laboratory Charges	102,555	102,362	89,655	89,462	102,555	102,362	15% of operating labor <sup>(c)</sup>
Plant Overhead	481,049	480,159	422,283	421,393	481,049	480,159	60% of operating/maintenance labor <sup>(c)</sup>

Table 6-10. Estimated Annual Operating Costs (continued)

Cost Item	Baseline	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Basis
<b>Waste Disposal</b>							
Topcoat applied with HVLP gun	3,095	3,095			3,095	3,095	\$10/gal <sup>(b)</sup>
Topcoat applied with improved gun			2,064	2,064			
BP primer	1,829		1,829		1,829		\$10/gal <sup>(b)</sup>
AP primer		1,829		1,829			
Painting materials	4,924	4,924	3,893	3,893	4,924	3,095	100% of paint/primer disposal costs <sup>(b)</sup>
Abrasives	42,904	42,904	42,904	42,904	42,904	42,904	\$0.58/lb <sup>(a)</sup>
<b>Insurance</b>	5,165	5,165	5,484	5,484	5,165	5,165	1% of FCI <sup>(c)</sup>
<b>Regulatory Compliance</b>	68,370	68,241	59,770	59,641	68,370	68,241	10% of operating labor <sup>(c)</sup>
<b>Total Annual Operating Costs</b>	1,796,760	1,788,453	1,574,039	1,565,488	1,796,516	1,786,624	
per painted area	2,703	2,888	2,542	2,928	2,901	2,885	per 1,000 ft <sup>2</sup>
Capital amortization	48,369	48,369	51,358	51,358	48,369	48,369	9.37% FCI (11 yrs service @ 6%)
per painted area	78	78	83	83	78	78	per 1,000 ft <sup>2</sup>
<b>Total cost</b>	1,845,129	1,836,822	1,625,397	1,616,846	1,844,855	1,834,993	
per painted area	2,981	2,966	2,625	2,611	2,979	2,963	per 1,000 ft <sup>2</sup>

(a) See Table 6 for basis references.

(b) Assumed based on standard values/practices.

(c) Peters and Timmerhaus, 1991.

**Table 6-11. Annualized Cost**

Cost Element	Baseline	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
<u>Annual operating cost:</u> \$1000/yr \$/1000 ft <sup>2</sup>	1,797 2,903	1,788 2,888	1,974 2,542	1,565 2,928	1,797 2,901	1,787 2,885
<u>Amortization:</u> \$1000/yr \$/1000 ft <sup>2</sup>	48 78	48 78	51 83	51 83	48 78	48 78
<u>Annualized cost:</u> \$1000/yr \$/1000 ft <sup>2</sup>	1,845 2,981	1,837 2,966	1,625 2,025	1,616 2,611	1,845 2,979	1,835 2,963

#### 6.4 Performance Evaluation

Descriptions of the scoring ranks for each of the performance evaluation parameters were provided in Section 4.

##### 6.4.1 Application Equipment

The Can-am system was reviewed independently and was found to provide a transfer efficiency of 90%, while maintaining acceptable surface quality. This is an increase in transfer efficiency of approximately 38%. The surface characteristics of the topcoat were found to be acceptable. It is being or has been used at several bases including Tobyhanna. Training for use of the alternative is believed to be minimal (< one day per man). However, due to some equipment failures at Tobyhanna they have not been able to completely rely on this system. There is insufficient supplemental information to determine if equipment failure is a point of major consideration.

The substantial improvement in transfer efficiency without noticeable loss in surface quality make the turbine HVLP system, or similar increased efficiency systems, appropriate for recommendation based on performance.

##### Surface Quality

Baseline      Acceptable (Martin, 1995; Miller, 1995; Hughes Aircraft Company, 1991 as reported in Cavendar et al., 1994)  
Rating: 2

Alternative    Acceptable (Tierney, 1995; Hughes Aircraft Company, 1991 as reported in Cavendar et al., 1994)  
Rating: 2

##### Transfer Efficiency (TE)

Baseline      T.E = 65% (Martin, 1995; Miller, 1995; Hughes Aircraft Company, 1991 as reported in Cavendar et al., 1994)  
Rating: 2

Alternative      T.E. = 90% (Tierney, 1995; Hughes Aircraft Company, 1991 as reported in Cavendar et al., 1994; Bunnell, 1995)  
Rating: 4

Ranking Delta

Surface Quality: 0    weight = 2  
Transfer Efficiency: 2    weight = 1  
Total after weighting:  $(2*0+1*2)/3 = +2/3$

**6.4.2 Primers**

The performance of the two primers (Baseline MIL-P-53022, Niles; Alternative MIL-P-53030, Deft) was viewed differently by different sources. Some users (Miller, 1995) expressed concern about adhesion between the primer and the topcoat, while others were not aware of this as a significant concern (Ewalt, 1995). It is not clear as to why there were occasional primer-topcoat adhesion problems. However, it is likely that different environmental conditions had some impact. Most paints, including primers, react differently to varying environmental conditions. One primer might perform better than a second primer when applied in a cool dry environment, but fail dramatically when applied under hot, humid conditions. Efforts to contact additional users (Ft. Hood: Chief Warrant Officer Ferrell, Sgt. Abrahamson and others) of both primers were unsuccessful due to their commitments. Further collection of opinions may have provided useful information, but could not be accomplished at this time.

Using the water thinnable alternative may require some minimal changes in application procedures, such as longer wait times between coats. This is needed because water used to thin the primer must evaporate before the topcoat is applied. Presence of water in the primer could cause premature curing of the topcoat and an inferior bond. Also, since the alternative primer is moisture thinnable, it is likely that under humid conditions it would absorb environmental moisture which would extend the wait time before the topcoat could be applied.

To appropriately analyze the effectiveness of the baseline and the alternative primer, a blind side-by-side comparison on similar targets under a range of temperature and humidity conditions should be made. Small test panels could be painted with both of the primers and a topcoat. The manufacturers' application recommendations should be strictly followed. If the adhesion between the two primers does not vary, then the improved ease of cleanup using water does make the alternative primer appropriate for recommendation based upon performance factors.

**Effect of Temperature and Humidity**

Baseline      Rating: 3, minimal impact not seen as having practical significance (Miller, 1995; Duncan, 1995)

Alternative      Rating: 2.5, a range of opinions describe the level of impact as a 2 and a 3 depending on the source (Miller, 1995; Duncan, 1995; Ewalt, 1995)

**Cure Rate**

Baseline      Rating: 3, cure rate had minimal effect on the painting schedule (Hale, 1995; Miller, 1995)

Alternative      Rating: 3, cure rate had minimal effect on the painting schedule (Miller, 1995; Duncan, 1995; Ewalt, 1995)

#### **Surface Pretreatment Requirements**

Baseline      Rating: 2, minimal cleaning with solvent rag required (Hale, 1995; Miller, 1995)

Alternative    Rating: 2, minimal cleaning with solvent rag required (Miller, 1995; Duncan, 1995; Ewalt, 1995)

#### **Ease of Primer Cleanup**

Baseline      Rating: 2, moderate effort required for cleanup (Hale, 1995; Miller, 1995)

Alternative    Rating: 3, minimal effort required for cleanup (Miller, 1995, Duncan, 1995, Ewalt, 1995)

#### **Ranking Delta**

Effect of Temperature and Humidity: weight = 3

Cure Rate: weight = 1

Surface Pretreatment Requirements: weight = 1

Ease of Primer Cleanup: weight = 1

Total after weighting:  $(3*(-0.5) + 1*0 + 1*0 + 1*0)/6 = -0.25.$

#### **6.4.3 Thinners**

The performance of the two thinners (Baseline: Mil-T-81772B; Alternative: Federal Standard A-A-857B) varied from user to user. The effects of environmental differences are again believed to be the reason for differences in performance opinions. Differences in the ability to thin the topcoat were not discernable. However, the effect on the surface characteristics of the topcoat was noticeable. The effect of the thinner on the appearance and performance of the topcoat needs to be evaluated by each base to determine the impact on the topcoat for their specific conditions. The amount of thinner required is not expected to be affected dramatically by the selection of either of the two thinners.

Even if the alternative thinner is found to be unacceptable for use with the topcoat it should be considered for use in cleaning of the guns and hoses. Since, the thinning effectiveness of the two thinners is similar, the alternative can be recommended for use as a cleaning solvent at a minimum based on performance. The use of the thinner in conjunction with the topcoat needs to be determined on a base by base comparison.

#### **Thinning Ratio or Thinner Effectiveness**

Baseline      4:1 ratio for CARC: Thinner (Woody, 1995; Miller, 1995)

Rating: 2

Alternative    4:1 ratio for CARC: Thinner (Woody, 1995; Miller, 1995)

Rating: 2

#### **Film Characteristics**

Rating: 3, minimal blemishes not believed significant (Woody, 1995; Miller, 1995)

Rating: 2.5, a range of opinions make describe the level of impact as a 2 and a 3 depending on the source (Woody, 1995; Miller, 1995)

#### **Ranking Delta**

Effectiveness: weight = 1

Film Characteristics: weight = 1

Total after weighting:  $(1*0 + 1*(-0.5))/2 = -0.25.$

## **6.5 Valuation Process**

The valuation process was conducted in a step-wise fashion, beginning with the construction of the hierarchy tree and continuing with the environmental, cost, and performance weighting, respectively. The "final" decision hierarchy is shown in Figure 6-4. The term "final" in quotes is used to ensure that the reader understands that the structure of the hierarchy is determined by the analyst and the technical team. There is no single correct hierarchy, only decision structures that appear to make sense in analyzing the weights to be assigned. Each of the three major decision dimensions, environment, cost, and performance, are shown at the topmost level of the hierarchy. In turn these are further divided according to criteria and subcriteria within each of the areas. The environmental criteria are first grouped by spatial/temporal scales into global (long term), regional (intermediate term), and local (short to intermediate) term issues.

This arrangement provides a useful framework for consideration of elements that would be important at the facility versus larger, national to societal levels. Within the global, regional and local criteria, further subdivision is made to facilitate assigning preferences in an intuitive manner. Within the cost dimension, only two criteria were identified, corresponding to the variable (O&M) versus fixed (capitalized) cost categories. Further breakdown within each of these criteria was not felt to offer additional potential for assignment of the weights. Finally, the performance dimension criteria were divided according to the application equipment, primer, or thinner component and then further into specific performance subcriteria relevant to each component.

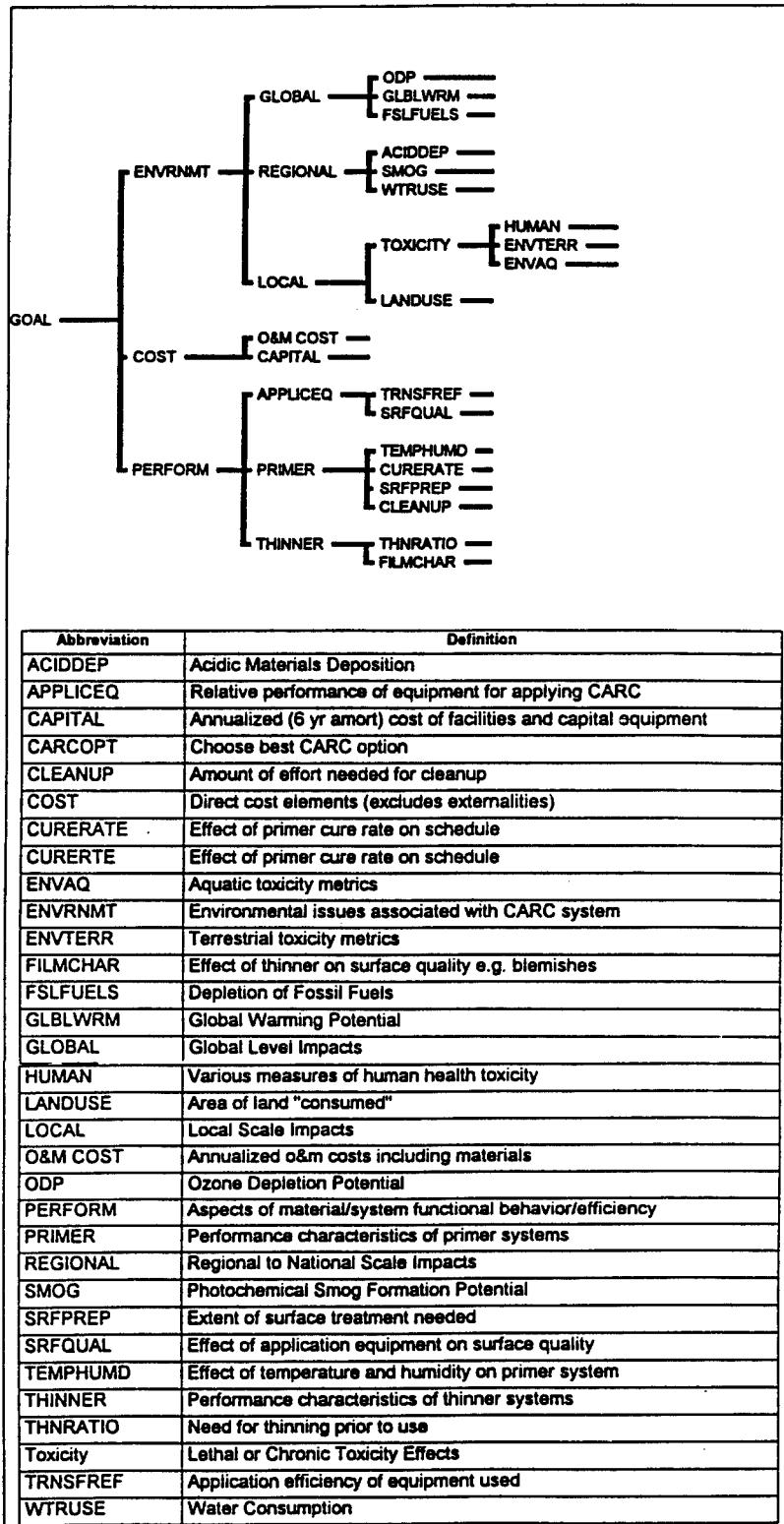


Figure 6-4. Structure of the analytic hierarchy for CARC alternatives.

The results of the weighting exercise assigned 65% of the value to the environmental dimension, 24% to the performance aspects, and 11% to the cost (Figure 6-5). This result should be viewed in the light of the scoping process where the threshold criteria were anticipated to result in alternatives that performed adequately and did not differ markedly in cost. Further tracing the weighting process into the three major branches indicates that global environmental issues were assigned approximately 32% of weight, or about half of the overall environmental contribution. Regional and local issues received 20% and 13%, respectively. In the cost branch, the O&M costs were considered approximately 3 times as important as the capital costs. Again, it should be borne in mind that the scoping exercise almost guaranteed that none of the alternatives would require a major capital expenditure. Finally, in the performance branch the primer was considered the most important with the thinner and gun receiving about equal consideration.

In each case the procedure for applying the valuation process to the impact assessment results was to create a "ruler" by normalizing the baseline impact scores to the highest value in each category. Then, the values for an alternative could be measured relative to that score. This produces a set of values that is internally consistent to the decision being made, but neither guarantees the metric is theoretically as robust as possible (i.e., its ability to differentiate alternatives in principle could be greater) nor allows decisions made in one setting to be compared to those made in another. As an example, recommendations made regarding CARC alternatives in this effort would not be comparable to those made about procuring plating equipment if that decision was made using a set of normalizing factors derived as part of that decision process.

## 6.6 Overall Improvement Assessment Results

The application of the valuation weights to the normalized impact scores is summarized in Tables 6-12 through 6-17 for the baseline and each of the alternatives. The score summaries (lower is preferable) are shown below in decreasing order:

Baseline:	1.191
Alternative Thinner:	1.134 (Alternative 4)
Alternative Primer:	1.019 (Alternative 1)
Alternative Thinner and Primer:	1.016 (Alternative 5)
Alternative Gun:	1.006 (Alternative 2)
Alternative Primer and Gun:	0.898 (Alternative 3).

These results indicate that the use of the alternative gun makes the largest potential improvement for an alternative that changes only a single factor, and combining this with the alternative primer results in the best CARC option. Therefore, it is recommended that the next phase of the effort include the demonstration of the alternative primer and gun combination. Also, a further scenario consisting of the alternative thinner, primer, and gun should be analyzed to assess whether this combination may be even better than the primer/gun combination.

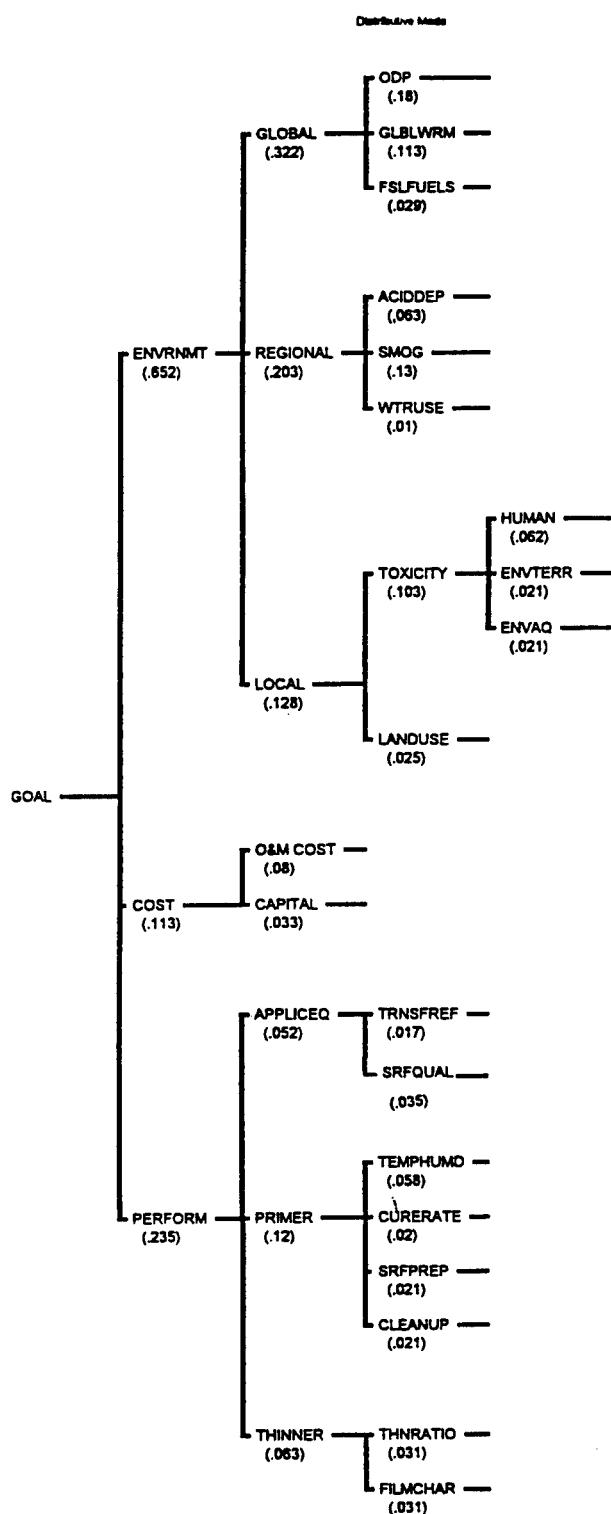


Figure 6-5. Overall weights derived for the valuation of CARC alternatives

**Table 6-12. Life Cycle Impact Valuation Calculations for Baseline**

CARCOPT	Scale	Issues ----->	AHP	Normalized	Weighted Normalized Factored Score	Baseline Score
			Weighting Factor	Factored Score		
GLOBAL	ODP	0.17983	1.090	0.196	0.347	1.191
	GLBLWRM	0.11328	1.013	0.115		
	FSLFUELS	0.02855	1.263	0.036		
REGIONAL	ACIDDEP	0.06253	1.198	0.075	0.220	
	SMOG	0.13007	1.114	0.145		
	WTRUSE	0.01002		0.000		
	LOCAL				0.276	
TOXICITY	HUMAN	0.06155	2.150	0.132	0.237	
	ENVERR	0.02052	3.799	0.078		
	ENVAQ	0.02052	1.280	0.026		
	LANDUSE	0.02507	1.577	0.040		
	COST				0.113	
O&M COST	O&M COST	0.08027	1.000	0.080	0.080	
	CAPITAL	0.03274	1.000	0.033		
PERFORM	APPLICEQ	TRNSFRE	0.01713	1.000	0.052	
		SRFQUAL	0.03522	1.000		
	PRIMER	TEMPHUM	0.05841	1.000	0.017	
		CURERAT	0.02013	1.000	0.035	
THINNER	SRFPREP	0.02072	1.000	0.020	0.120	
		CLEANUP	0.02057	1.000	0.021	
	THNRATIO	0.03144	1.000	0.021	0.063	
FILMCHAR	FILMCHAR	0.03144	1.000	0.031	0.031	

Table 6-13. Life Cycle Impact Valuation Calculations for Alternative Primer

		AHP Weighting Factor	Normalized Factored Score	Weighted Normalized Factored Score	Alternative No. 1 Score
Scale	Issues ---->				
CARCOPT	GLOBAL				1.019
	ODP	0.17983	0.367	0.066	0.203
	GLBLWRM	0.11328	0.927	0.105	0.203
	FSLFUELS	0.02855	1.121	0.032	0.203
REGIONAL	ACIDDEP	0.06253	1.173	0.073	0.266
	SMOG	0.13007	0.993	0.129	
	WTRUSE	0.01002		0.000	
LOCAL	TOXICITY				
	HUMAN	0.06155	1.612	0.099	
	ENVTERR	0.02052	2.635	0.054	
	ENVAQ	0.02052	3.537	0.073	
	LANDUSE	0.02507	1.585	0.040	
	COST				0.226
	O&M COST	0.08027	0.995	0.080	0.113
	CAPITAL	0.03274	1.000	0.033	
PERFORM	APPLICEQ				0.236
	TRANSFRE	0.01713	1.000	0.017	
	SRFQUAL	0.03522	1.000	0.035	
	PRIMER				0.052
	TEMPHUM	0.05841	0.833	0.049	
	CURERAT	0.02013	1.000	0.020	
	SRFPREP	0.02072	1.000	0.021	
	CLEANUP	0.02057	1.500	0.031	
	THINNER				0.063
	THNRATIO	0.03144	1.000	0.031	
	FILMCHAR	0.03144	1.000	0.031	

**Table 6-14. Life Cycle Impact Valuation Calculations for Alternative Gun**

Scale	Issues ----->	AHP		Normalized Factored Score	Weighted Normalized Factored Score	Alternative No. 2 Score
		Weighting Factor	AHP Factor			
<b>CARCOPT</b>						
GLOBAL						1.006
ODP	0.17983	0.799		0.144	0.254	
GLBLWRM	0.11328	0.739		0.084		
FSLFUELS	0.02855	0.929		0.027		
REGIONAL						0.174
ACIDDEP	0.06253	1.116		0.070		
SMOG	0.13007	0.800		0.104		
WTRUSE	0.01002			0.000		
LOCAL						0.202
TOXICITY						
HUMAN	0.06155	1.510		0.093		
ENVTERR	0.02052	2.565		0.053		
ENVAQ	0.02052	0.925		0.019		
LANDUSE	0.02507	1.493		0.037		
COST						0.105
O&M COST	0.08027	0.876		0.070		
CAPITAL	0.03274	1.064		0.035		
PERFORM						0.271
APPLICEQ						
TRNSFRE	0.01713	1.000		0.017		
SRFQUAL	0.03522	2.000		0.070		
PRIMER						0.120
TEMPHUM	0.05841	0.833		0.049		
CURERAT	0.02013	1.000		0.020		
SRFPREP	0.02072	1.000		0.021		
CLEANUP	0.02057	1.500		0.031		
THINNER						0.063
THNRATIO	0.03144	1.000		0.031		
FILMCHAR	0.03144	1.000		0.031		

Table 6-15. Life Cycle Impact Valuation Calculations for Alternative Primer and Gun

Scale	Issues .....>	AHP Weighting Factor	Normalized Factored Score	Alternative No. 3 Score	
					Weighted Normalized Factored Score
CARCOPT	GLOBAL			0.898	
	ODP	0.17983	0.265	0.148	0.048
	GLBLWRM	0.11328	0.677	0.162	0.077
	FSLFUELS	0.02855	0.827		0.024
REGIONAL	ACIDDEP	0.06253	1.098		0.069
	SMOG	0.13007	0.721		0.094
	WTRUSE	0.01002			0.000
				0.201	
LOCAL	TOXICITY			0.164	
	HUMAN	0.06155	1.172	0.072	0.072
	ENVTERR	0.02052	1.906	0.039	0.052
	ENVAQ	0.02052	2.554	0.038	0.035
COST	LANDUSE	0.02507	1.497	0.116	
	O&M COST	0.08027	1.009		0.081
	CAPITAL	0.03274	1.064		0.035
				0.271	
PERFORM	APPLICEQ			0.088	
	TRANSFRE	0.01713	1.000	0.017	
	SRFQUAL	0.03522	2.000	0.070	
	PRIMER			0.120	
PRIMER	TEMPHUM	0.05841	0.833	0.049	
	CURERAT	0.02013	1.000	0.020	
	SRFPREP	0.02072	1.000	0.021	
	CLEANUP	0.02057	1.500	0.031	
THINNER	THNRATIO	0.03144	1.000	0.031	
	FILMCHAR	0.03144	1.000	0.031	

Table 6-16. Life Cycle Impact Valuation Calculations for Alternative Thinner

Scale Issues .....>		AHP Weighting Factor	Normalized Factored Score	Weighted Normalized Factored Score	Alternative No. 4 Score
CARCOPT	GLOBAL				1.134
	ODP	0.17983	1.106	0.199	
	GLBLWRM	0.11328	0.905	0.103	
	FSLFUELS	0.02855	1.133	0.032	
REGIONAL	ACIDDEP	0.06253	1.187	0.074	
	SMOG	0.13007	1.035	0.135	
	WTRUSE	0.01002		0.000	
LOCAL	TOXICITY			0.249	
	HUMAN	0.06155	1.997	0.123	
	ENVERR	0.02052	2.918	0.060	
	ENVAQ	0.02052	1.279	0.026	
	LANDUSE	0.02507	1.577	0.040	
COST	O&M COST	0.08027	0.999	0.080	
	CAPITAL	0.03274	1.000	0.033	
PERFORM	APPLICEQ			0.052	
	TRANSFRE	0.01713	1.000	0.017	
	SRFQUAL	0.03522	1.000	0.035	
PRIMER				0.120	
	TEMPHUM	0.05841	1.000	0.058	
	CUREAT	0.02013	1.000	0.020	
	SRFPREP	0.02072	1.000	0.021	
	CLEANUP	0.02057	1.000	0.021	
THINNER				0.058	
	THNRATIO	0.03144	1.000	0.031	
	FILMCHAR	0.03144	0.833	0.026	

Table 6-17. Life Cycle Impact Valuation Calculations for Alternative Primer and Thinner

Scale	Issues .....>	AHP Weighting Factor	Normalized Factored Score	Weighted Normalized Factored Score	Alternative No. 6 Score
					1.016
<b>CARCOPT</b>					
GLOBAL	ODP	0.17983	0.367	0.066	0.198
	GLBLWRM	0.11328	0.893	0.101	
	FSLFUELS	0.02855	1.086	0.031	
<b>REGIONAL</b>					
ACIDDEP	0.06253	1.168	0.073	0.202	
SMOG	0.13007	0.989	0.129		
WTRUSE	0.01002		0.000		
<b>LOCAL</b>					
TOXICITY	HUMAN	0.06155	1.700	0.105	
	ENVTERR	0.02052	2.767	0.057	
	ENVAQ	0.02052	3.538	0.073	
	LANDUSE	0.02507	1.585	0.040	
<b>COST</b>					
O&M COST	0.08027	0.994	0.080	0.113	
CAPITAL	0.03274	1.000	0.033		
<b>PERFORM</b>					
APPLIEQ	TRANSFRE	0.01713	1.000	0.017	
	SRFQUAL	0.03522	1.000	0.035	
<b>PRIMER</b>					
	TEMPHUM	0.05841	0.833	0.049	
	CURERAT	0.02013	1.000	0.020	
	SRFPREP	0.02072	1.000	0.021	
	CLEANUP	0.02057	1.500	0.031	
<b>THINNER</b>					
	THNRATIO	0.03144	1.000	0.031	
	FILMCHAR	0.03144	0.833	0.026	

## **7.0 Implementation Plan**

Previous sections have developed information on the environmental, cost, and performance aspects of five alternative CARC systems and combined this information through the use of a valuation process to provide an overall prioritization of the screened options. The results indicated that certain of the options provide significantly lower environmental hazard potential with minimal impact on cost and no discernable performance impairment. However, in order to implement the findings, there may be non-technical and non-economic issues to be dealt with. These areas include a lack of demonstrated application of the alternative in actual production operations, considerations relating to procurement practices of either materials or capital, and any incremental training of operators to use and properly dispose of the alternative equipment and materials. This section addresses these types of considerations.

### **7.1 Performance Demonstration**

Performance demonstration refers to the actual painting of vehicles using the alternative system(s). Although the constraints established during the scoping exercise should be sufficient to ensure a reasonably high probability of success in implementing the alternative gun and/or primer system, it will likely be necessary to demonstrate their effectiveness prior to widespread adoption by the Army.

#### ***7.1.1 Application Equipment***

The manufacturer should be able to recommend and demonstrate the necessary gun, nozzle, tip, and pressures for optimum coating with minimal thinning of all used coatings (primer and topcoat along with other non-CARC related coatings). Some manufacturers demonstrate the capabilities of a piece of equipment with a generic paint that highlights the optimum range of the equipment. Therefore, it is advisable that the manufacturer is instructed that the equipment will not be purchased without a demonstration of its use with the paints that are to be applied. Issues such as power and space requirements should also be discussed at this time. Any necessary modifications to the analysis should be incorporated before a final decision is made.

#### ***7.1.2 Primer***

The major issue of the alternative primer is adhesion to the CARC topcoat. The level of adhesion between the primer and the topcoat can be influenced both by local environmental conditions and variations in topcoats amongst the different manufacturers. To determine local influences, the currently used primer and the alternative primer should be applied to test panels according to the manufacturer's recommendations. Topcoats should then be applied over the primers. Once the topcoat has been applied and allowed to cure, a cross-hatch adhesion test (ASTM D3359) should be used to check for adhesion between the primer and the topcoat. This procedure should be repeated periodically to test for the effects of changing environmental conditions. If any negative effects are noticed, then the temperature and humidity conditions should be noted along with any other changes in procedures that may have occurred. If the primer is found to perform poorly under certain conditions, then it may need to be limited to seasonal use. Again, any implications of this should be factored back into the analysis.

### **7.1.3 Thinner**

A purchase of one gallon of the alternative thinner can easily be used for a performance evaluation. The thinner should be added to the CARC topcoat material until sprayable viscosity is achieved. The thinned topcoat should then be applied to a primed test panel. The surface should then be visually compared to a surface topcoated using the baseline thinner or currently used thinner. This procedure should also be repeated periodically to test for influences of changes in environmental conditions.

Comparisons of the change in viscosity of the currently used CARC topcoat due to equal additions of baseline or alternative thinner can also be measured. Typically, the difference in the effect on viscosity has not been noticeable. However, variations in topcoat formulations between manufacturers may result in more significant differences in thinner effectiveness. It is unlikely that the amount of alternative thinner will be measurably higher than that of the baseline. However, based on the foregoing analysis, if the amount of alternative thinner required is more than a modest percentage greater than that of the baseline, it will no longer provide a detectable advantage in terms of an environmental benefit.

## **7.2 Procurement Considerations**

This implementation issue area addresses two considerations. One, if the alternative involves a capital item acquisition, it would be desirable to explore what steps might be necessary to justify its purchase and also to understand who would make the decision, particularly when the painting operations may not be performed by Army personnel. Second, if the materials used are not those currently being procured, it should be questioned how much of an issue it would be to change the procurement specification, especially if the initial cost is higher. Responses to these questions from the base personnel were used to formulate the information provided below. It should be noted that an exhaustive survey was not performed. It is possible that some locations may have more stringent requirements than those cited. However, the information presented is believed to be reasonably representative.

### **7.2.1 Application Equipment**

The acquisition of a turbine HVLP system should require no approval beyond acceptance of the item managers involved. The item managers for the painted targets have the ultimate approval for how an item is painted. However, as long as the coated parts meet quality standards, the specific components or methods used are generally not an issue. Therefore, once the alternatives have been found acceptable via the performance demonstration, there should not be additional approval requirements.

The purchase price of a turbine system (approximately \$20,000 for four guns and a turbine) is significantly more than that of traditional HVLP equipment and thus merits additional considerations. This price and the presence of some information suggesting possible reliability problems may justify requesting or requiring a lease option. A lease would allow for the investigation of new equipment as it becomes available. Due to the competitive nature of the equipment manufacturers market, it is likely that other, less expensive equivalent turbine systems will be marketed in the next few years. Also, a service agreement which includes next day loaner equipment might prove invaluable, since the occurrence of downtime at key periods cannot be accepted.

### **7.2.2 Primers and Thinners**

The primer and the thinner should also require no approval beyond the acceptance of the item managers. This acceptance should be received after the two alternatives have passed the performance demonstrations. Since both the alternative thinner and primers are either Military-Specified or Federal-Standard-Approved, they should be obtainable through the standard procurement channels. The Federal Stock Classes (FSCs), National Item Identification Number

(NIIINs), manufacturer's CAGE numbers and Part Name/Number of the materials reviewed are available in the MSDSs provided.

### **7.3 Training Requirements**

#### ***7.3.1 Application Equipment***

The alternative application equipment, the Can-am turbine HVLP system, has been used at several locations and found to require only a few hours per man of familiarization. Safety concerns should be similar to those of standard HVLP equipment with the additional concerns of slightly larger air lines and the turbine itself. However, a demonstration by the manufacturer which includes discussions of safety and technique issues should still be utilized.

#### ***7.3.2 Primers and Thinners***

There are no known new special handling requirements or training issues associated with the alternative primer or the alternative thinner. The same safety methods that are used for the current baselines should be followed. MSDS sheets should be read by each user and special consideration should be taken in the case of users who have sensitivities to certain chemicals. The primer is an amine-cured epoxy like the baseline and these systems have been associated with increased sensitivity among some users over time. The differences in the manufacturing of the alternative epoxy-amine system may have an effect on the rate of sensitization.

Some minor alterations in the application equipment's setup may be required to achieve optimum performance for the alternatively thinned topcoat and the alternative primer. The primer may also require slightly different application thicknesses or drying times between recoats. This information is available from the manufacturers. Finally, the thinner might change the curing rate of the topcoat and minor changes in scheduling may be required.

## 8.0 Conclusions

The analysis undertaken during the study leads to conclusions in two areas:, LCImA methodology and specific findings of the CARC case study. In the former, the results of the effort indicate:

- an LCA-based methodology for DfE is viable and leads to both broader and more cohesive insights into the tradeoffs among decision elements,
- the use of a valuation methodology, although not essential, makes it easier for the decision maker to identify preferred alternatives,
- aspects of the LCImA methodology are still limited in two ways; one, the analytic framework associated with the impact characterization could benefit from additional refinement efforts relative to the normalization step and two, there are data gaps and deficiencies in both the inventory and the impact assessment that must be carefully assessed before conclusions are drawn,
- the DfE approach, while applicable to the development of processes/procedures and their implementation, likely would fit better with a true LCA-based design exercise for a product.

In the area of application to the CARC case study, the following conclusions are drawn:

- the LCImA effort provided an excellent framework for the analysis -- CARC specialists, cost engineers, and environmental scientists were able to coherently address and integrate the various aspects of their work into a combined analysis that clearly identifies the tradeoffs involved,
- of the five alternatives considered, two of them (alternative gun and a combination of alternative primer and gun) demonstrate the potential for clear environmental improvement; the remaining three exhibit slight improvements that are not significant within the uncertainty of the analysis,
- when cost and performance are considered simultaneously with environment, the same two alternatives emerge as the preferred candidates for implementation but the degree of differentiation relative to the baseline is less. This may be understood in the light of the valuation process which assigns a level of influence in the final analysis to each of the three improvement assessment dimensions. When considered alone, environmental factors obviously exert all of the differentiating ability. When cost and performance considerations are added, the nature of the scoping process in this application limited the alternatives to those that were not expected to be strongly differentiable on these two dimensions. Thus, when the combined influence ascribed to these factors (35%) is considered, the overall differentiation magnitude is decreased. Nevertheless, Alternative 3 (primer and gun) still

clearly emerges as the recommended implementation choice followed by Alternative 2 (gun only).

## **9.0 Bibliography**

Aldrich Chemical Company. 1992. Catalog Handbook of Fine Chemicals. 1992-1993 ed. Aldrich Chemical Company, Milwaukee, WI. 1992 pp.

Brown, H.L., B.B. Hamel, and B.A. Hedman. 1985. Energy Analysis of 108 Industrial Process. Fairmont Press, Philadelphia, PA. 314 pp.

Bunnell, M. 1995. Telephone conversation between Mr. Mike Bunnell, President, Can-am and Mr. Kevin Taylor, Battelle, August 28, 1995.

Cavender, K., S. Piccot, M. Tedijanto, and D. Russell. 1994. Pollution Prevention Opportunity Assessment: Chemical Agent Resistant Coating Operation at Ft. Eustis, Virginia. Draft Report. Prepared by Southern Research Institute, and Pacific Environmental Services, Incorporated for the U. S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Office of Research and Development, Cincinnati, OH.

*Chemical Marketing Reporter*. vol. 247. Jan-Jun 1995. Schnell Publishing Co., New York, NY.

Department of the Army Technical Bulletin, 1991. *CARC Spot Painting*. Headquarters, Department of the Army.

Duncan, J. 1995. Multiple telephone conversations between Jeff Duncan, Fort Belvoir Army Paint Research Facility and Kevin Taylor, Battelle, March 1995. Information is a composite of several communications between Mr. Duncan and Mr. Taylor.

Ellis, W. 1986. Solvents. Federation Series on Coatings Technology. Federation Series on Coating Technologies, Philadelphia, PA, October, 29 pp.

Ewalt, L. 1995. Multiple telephone conversations between Mr. Leon Ewalt, technical representative, Deft and Mr. Kevin Taylor, Battelle, July 95.

Gmelin. 1932. Gmelins Handbuch der Anorganischen Chemie. Teil A, System Number 58. p 479.

Gmelin. 1961. Gmelins Handbuch der Anorganischen Chemie. Supplement pp 58-61.

Hale, J. 1995. Telephone conversation between Jerry Hale, Supervisor of CARC painting operations Ft. Eustits and Kevin Taylor, Battelle, July, 26, 1995. Results are based on conclusions drawn by Mr. Taylor from information obtained from conversations with Mr. Hale.

Heijungs, R. (Final Editor). 1992a. Environmental Life-Cycle Assessment of Products: Guide - October 1992. Report 9266. CML (Centre of Environmental Science) in Leiden, TNO (Netherlands Organisation for Applied Scientific Research) in Apeldoorn, and B&G (Fuels and Raw Materials Bureau) in Rotterdam, The Netherlands. 96 pp.

Heijungs, R. (Final Editor). 1992b. Environmental Life-Cycle Assessment of Products: Backgrounds - October 1992. Report 9267. CML (Centre of Environmental Science) in Leiden, TNO (Netherlands Organisation for Applied Scientific Research) in Apeldoorn, and B&G (Fuels and Raw Materials Bureau) in Rotterdam, The Netherlands. 130 pp.

Hendricks, D., R. Purcell, M. Tedijanto, and D. Russell. 1995. Life Cycle Inventory for Chemical Agent Resistant Coating. Draft Report. Prepared by Pacific Environmental Services, Incorporated for the U. S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Office of Research and Development, Cincinnati, OH.

Hocking, M.B. 1985. Modern Chemical Technology and Emission Control. Springer-Verlag, New York. 460 pp.

Kirk-Othmer. 1978. Kirk-Othmer Encyclopedia of Chemical Technology. 3rd Edition.. Wiley Interscience, New York, NY.

Kirk-Othmer. 1991. Kirk-Othmer Encyclopedia of Chemical Technology. 4th Edition. Wiley Interscience, New York, NY.

Lowenheim, F.A., and M.K. Morgan. 1975. Faith, Keyes, and Clark's Industrial Chemicals. 4th Edition. Wiley-Interscience, New York. 904 pp.

Martin, J. 1995. Telephone conversation between Jimmy Martin, Sales Representative for Binks and Kevin Taylor, Battelle, 8/4/1995.

Mayer, S. 1994. Personal communication, Nick Conkle to Steve Mayer, June 23, 1994 (Mayer was in charge of waste blasting-media disposal)

McKetta. John J., Ed. 1992. Chemical Processing Handbook. Marcel Dekker, Inc., New York, NY. 972 pp.

Merck. 1983. The Merck Index. 10th ed. Merck & CO, Rahway, NJ.

Miller, T. 1995. Telephone conversations and facsimile questionnaire between Tom Miller, Northrop Worldwide Aircraft Services (subcontracted by Fort Eustis to perform the painting) and Kevin Taylor Battelle, August 9-11, 1995. Results are based on conclusions drawn by Mr. Taylor from information obtained from conversations with Mr. Miller.

Monzyk, B.F. 1995. Personal communication to J.R. Becker, Battelle by B.F. Monzyk, Chemical Process Engineer at Battelle (previously employed by Monsanto), August 10.

Nordic Council. 1992. Product Life Cycle Assessment - Principles and Methodology. The Nordic Council, Stockholm, Sweden. 288 pp.

Peters, M.S., and K.D. Timmerhaus. 1991. Plant Design and Economics for Chemical Engineers. 4th Edition. McGraw-Hill, Inc., New York, NY. 910 pp.

Saaty, T.L. 1990. The Analytic Hierarchy Process. RWS Publications, Pittsburgh, PA. 287pp.

Society of Environmental Toxicology and Chemistry (SETAC). 1991. A Technical Framework for Life-Cycle Assessments. Society of Environmental Toxicology and Chemistry, and SETAC Foundation for Environmental Education, Inc., Washington, DC. 134pp.

Society of Environmental Toxicology and Chemistry (SETAC). 1993. A Conceptual Framework for Life-Cycle Impact Assessment. Society of Environmental Toxicology and Chemistry, and SETAC Foundation for Environmental Education, Inc., Pensacola, FL. 160pp.

Society of Environmental Toxicology and Chemistry (SETAC). 1994. Life-Cycle Assessment Data Quality: A Conceptual Framework . Society of Environmental Toxicology and Chemistry, and SETAC Foundation for Environmental Education, Inc., Pensacola, FL. 157pp.

Seffick, S. 1995. Telephone conversation between Mr. Steve Seffick, sales representative, DeVilbiss and Mr. Kevin Taylor, Battelle July 24, 1995.

Sittig, M. 1975. Environmental Sources and Emissions Handbook. Noyes Data Corporation, Park Ridge, NJ. 523 pp.

Skillen, A. 1994. "Abrasive Blast Cleaning: Evolution or Revolution," Industrial Minerals, February, pp. 25-39.

SRI International. 1993. 1993 Directory of Chemical Producers. SRI International, Menlo Park, CA.

TRI. 1993. 1993 Toxic Release Inventory. On-line database available through TOXNET in the MEDLARS Clearinghouse offered by the National Library of Medicine, National Institutes of Health, U.S. Department of Health and Human Services, Bethesda, MD.

U.S. Bureau of Mines. 1992. 1992 Minerals Yearbook: Volume I, Metals and Minerals. U.S. Department of the Interior, Bureau of Mines, U. S. Government Printing Office, Washington, DC., 1,495 pp.

U.S. Bureau of Mines. 1995a. Mineral Industry Surveys: Chromium in 1994. Minerals Commodity Summaries -- January. U.S. Department of the Interior, Bureau of Mines, Washington, DC., 4 pp.

U.S. Bureau of Mines. 1995b. Minerals Commodity Summaries 1995: Cobalt. FaxBack Document. U.S. Department of the Interior, Bureau of Mines, Washington, DC., 2 pp.

U.S. Bureau of Mines. 1995c. Minerals Commodity Summaries 1995: Iron Ore. FaxBack Document. U.S. Department of the Interior, Bureau of Mines, Washington, DC., 2 pp.

U.S. Bureau of Mines. 1995d. Minerals Commodity Summaries 1995: Salt. FaxBack Document. U.S. Department of the Interior, Bureau of Mines, Washington, DC., 2 pp.

U.S. Bureau of Mines. 1995e. Minerals Commodity Summaries 1995: Magnesium. FaxBack Document. U.S. Department of the Interior, Bureau of Mines, Washington, DC., 2 pp.

U.S. Bureau of Mines. 1995f. Minerals Commodity Summaries 1995: Zinc. FaxBack Document. U.S. Department of the Interior, Bureau of Mines, Washington, DC., 2 pp.

U.S. Bureau of Mines. 1995g. Minerals Commodity Summaries 1995: Bauxite and Alumina. FaxBack Document. U.S. Department of the Interior, Bureau of Mines, Washington, DC., 2 pp.

U.S. Bureau of Mines. 1995h. Minerals Commodity Summaries 1995: Soda Ash. FaxBack Document. U.S. Department of the Interior, Bureau of Mines, Washington, DC., 2 pp.

U.S. Bureau of Mines. 1995i. Minerals Commodity Summaries 1995: Thallium. FaxBack Document. U.S. Department of the Interior, Bureau of Mines, Washington, DC., 2 pp.

U.S. Bureau of Mines. 1995j. Minerals Commodity Summaries 1995: Stone (Crushed). FaxBack Document. U.S. Department of the Interior, Bureau of Mines, Washington, DC., 2 pp.

U.S. Bureau of Mines. 1995k. Minerals Commodity Summaries 1995: Phosphate Rock. FaxBack Document. U.S. Department of the Interior, Bureau of Mines, Washington, DC., 2 pp.

U.S. Department of Energy. 1993. Annual Energy Review 1992. Energy Information Administration, U.S. Department of Energy, Washington, DC., 350 pp.

U.S. Environmental Protection Agency (EPA). 1976. Quality Criteria for Water. U.S. Environmental Protection Agency, Washington, DC, 256 pp.

U.S. Environmental Protection Agency (EPA). 1977. Industrial Process Profiles for Environmental Use. EPA-600/2-77-023. Cincinnati, Ohio.

U.S. Environmental Protection Agency (EPA). 1990. AIRS Facility Subsystem Source Classification Codes & Emission Factor Listing for Criteria Air Pollutants. EPA 450/4-90-003. Office of Air Quality Planning & Standards: Technical Support Division: Monitoring & Reports Branch, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (EPA). 1993a. Life Cycle Design Guidance Manual: Environmental Requirements and the Product System. EPA600/R-92/226. Prepared by the National Pollution Prevention Center, University of Michigan for the Risk Reduction Engineering Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH. 181 pp.

U.S. Environmental Protection Agency (EPA). 1993b. Life-cycle Assessment: Inventory Guidelines and Principles. EPA/600/R-92/245. Prepared by Battelle and Franklin Associates, Inc. for the Risk Reduction Engineering Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH. 108pp.

U.S. Environmental Protection Agency (EPA). 1994. Chemical Hazard Evaluation for Management Strategies: A Method for Ranking and Scoring Chemicals by Potential Human Health and Environmental Impacts. Risk Reduction Engineering Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH, 95 pp.

Wells, G. Margaret. 1991. Handbook of Petrochemicals and Processes. Gower Publishing Company, England.

Wicks, Z.W., Jr. 1987. Corrosion Protection by Coatings. Federation Series on Coatings Technology. Federation of Societies for Coatings Technology, Philadelphia, PA, February, 21 pp.

Woody, G. 1995. Telephone conversation between Gene Woody, Supervisor of CARC painting operations Ft. Campbell and Kevin Taylor, Battelle, July 21, 1995. Results are based on conclusions drawn by Mr. Taylor from information obtained from conversations with Mr. Woody.

Young, J.S., L. Ambrose, and L. Lobo. 1994. Stirring Up Innovation: Environmental Improvements in Paints and Adhesives. Inform, Inc., New York, NY. 116 pp.

APPENDIX A  
PROCESS FLOW DIAGRAMS

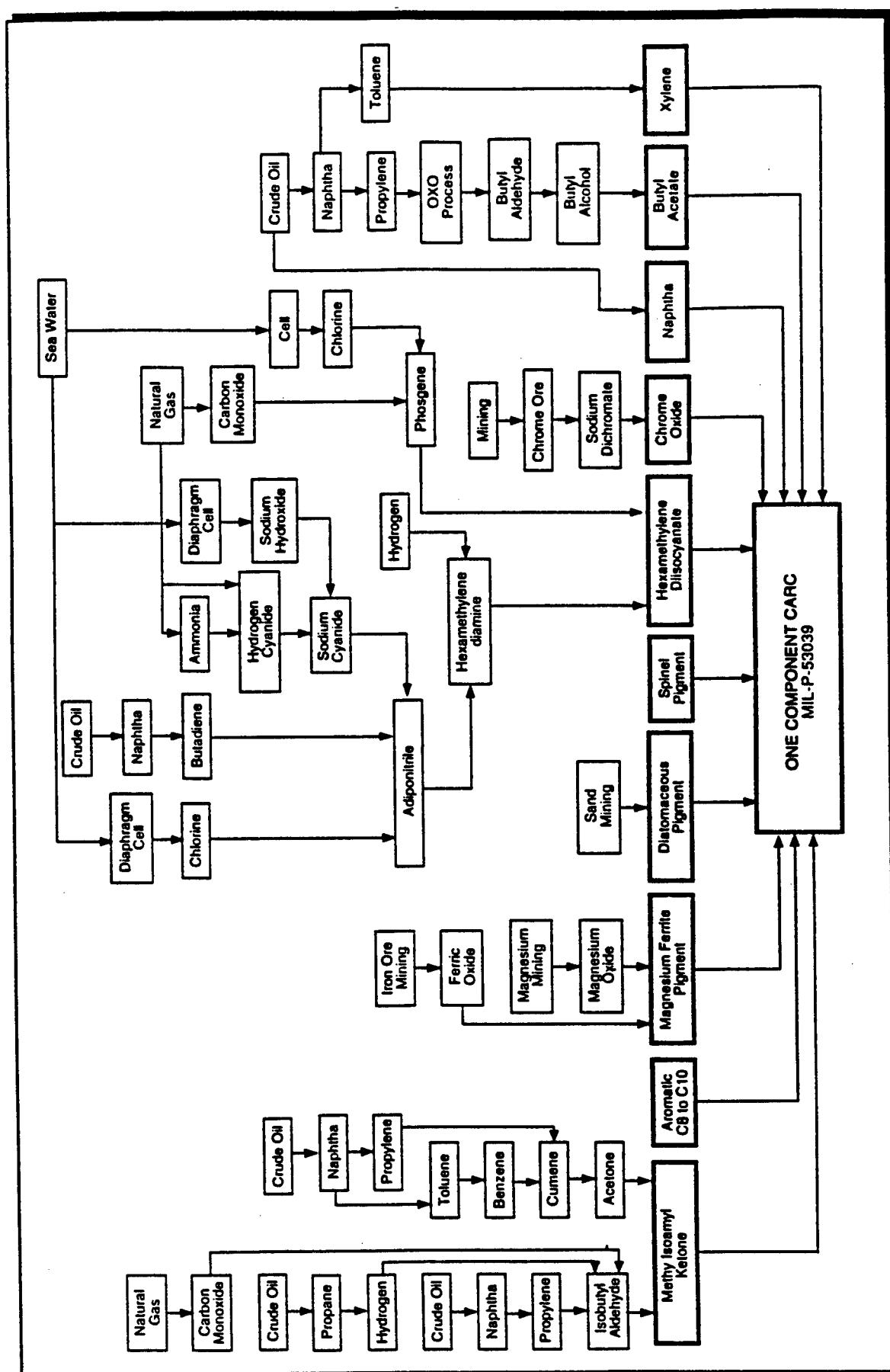
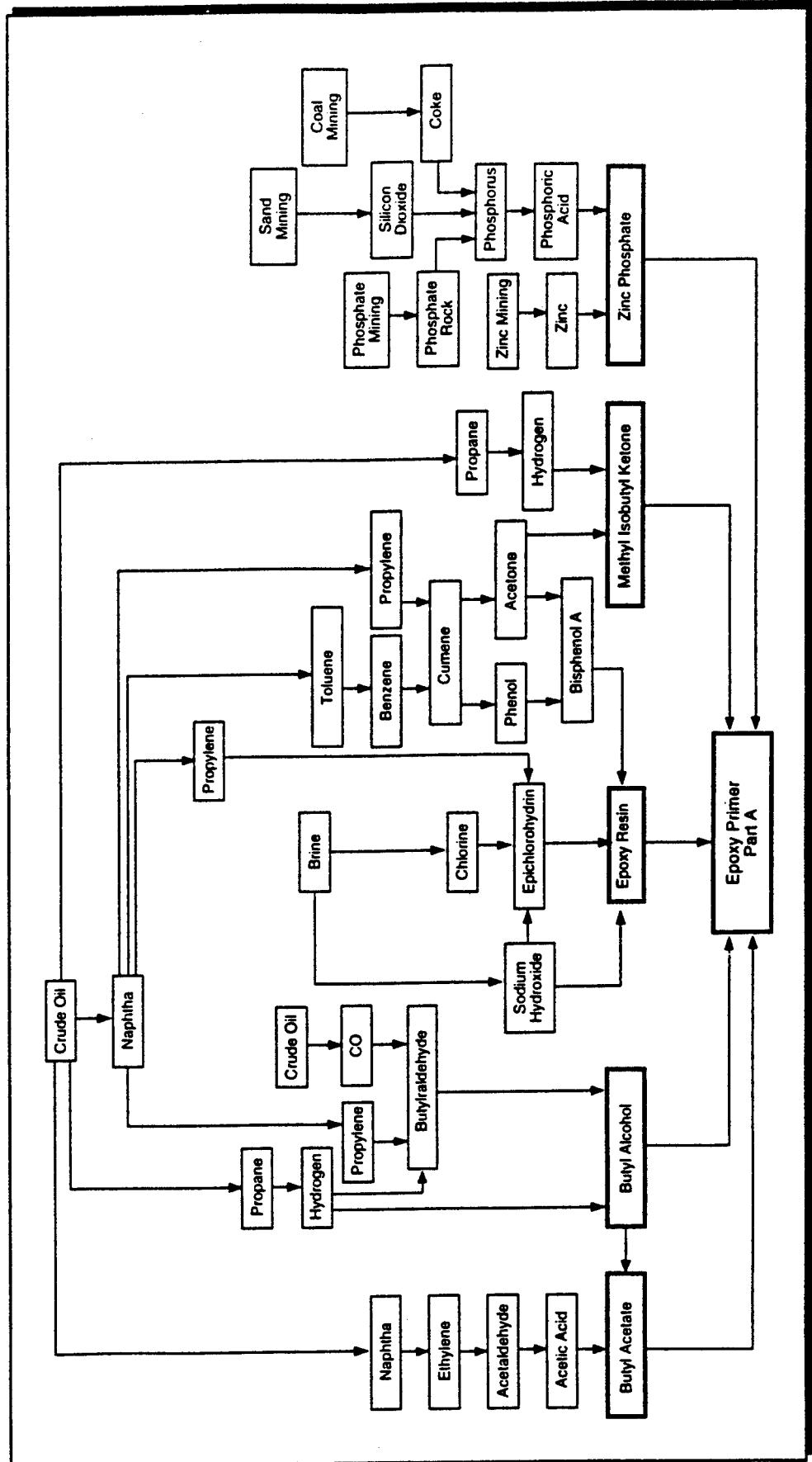
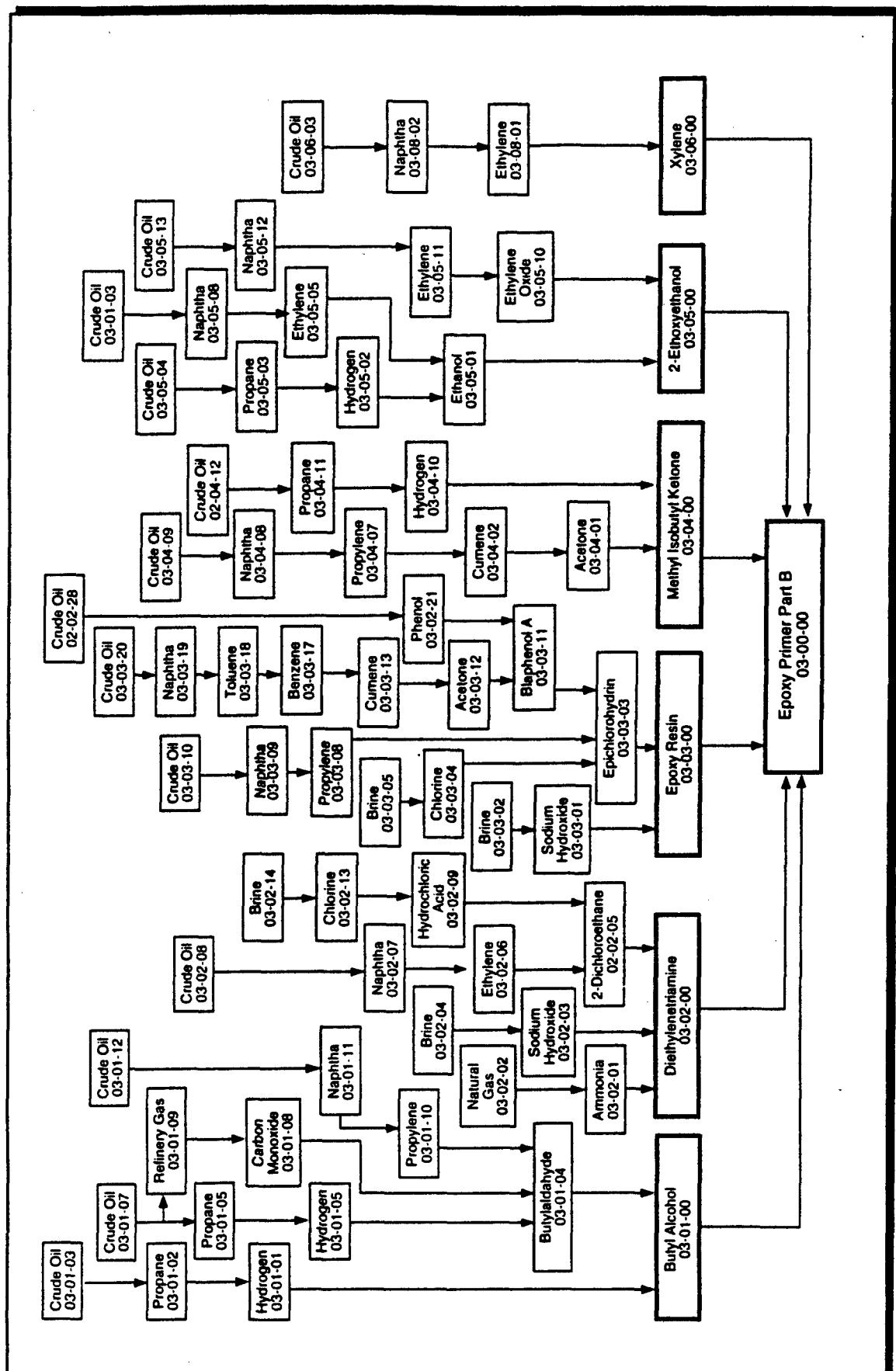


Figure A-1. Process flowsheet for one-component CARC

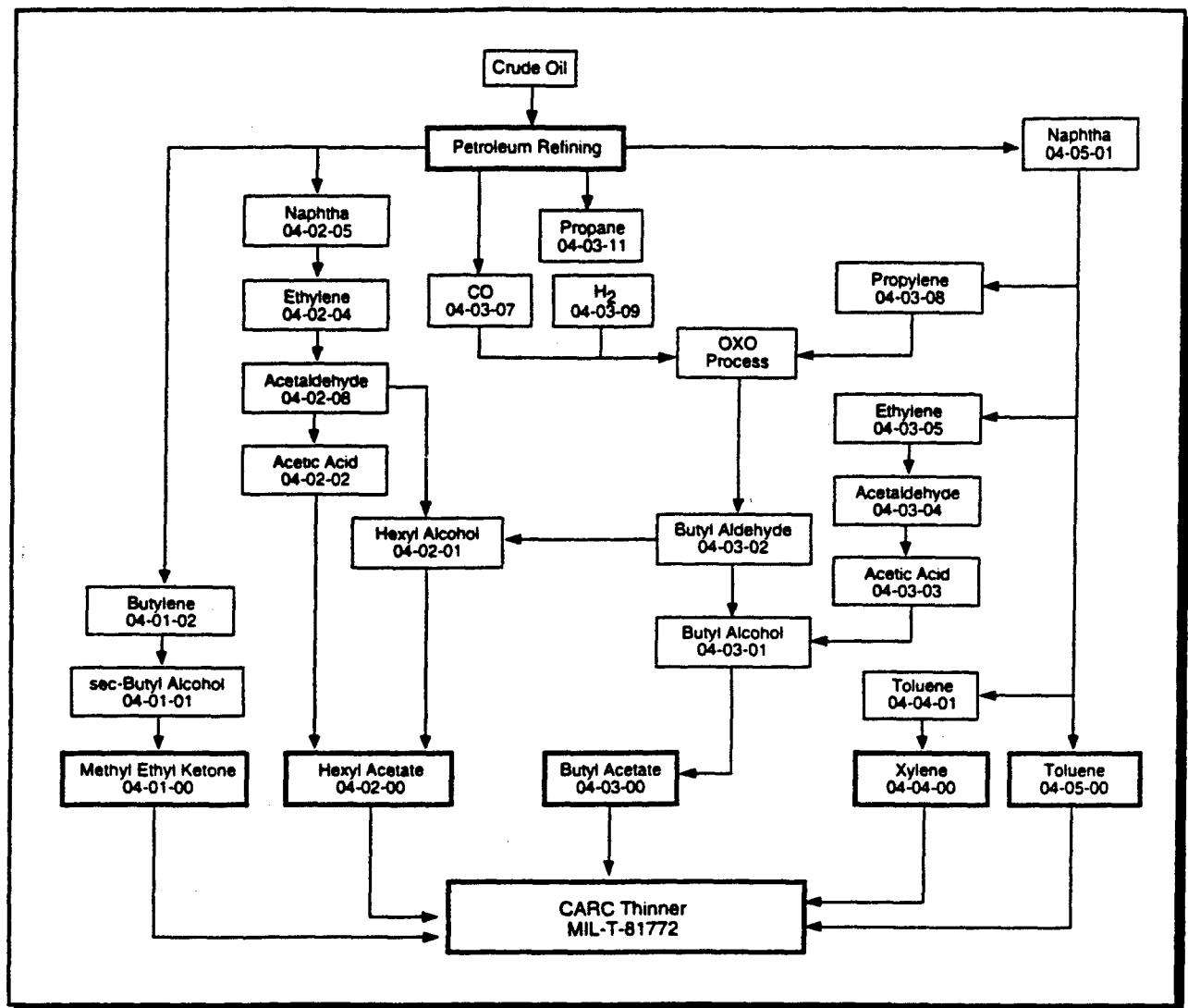


A-2

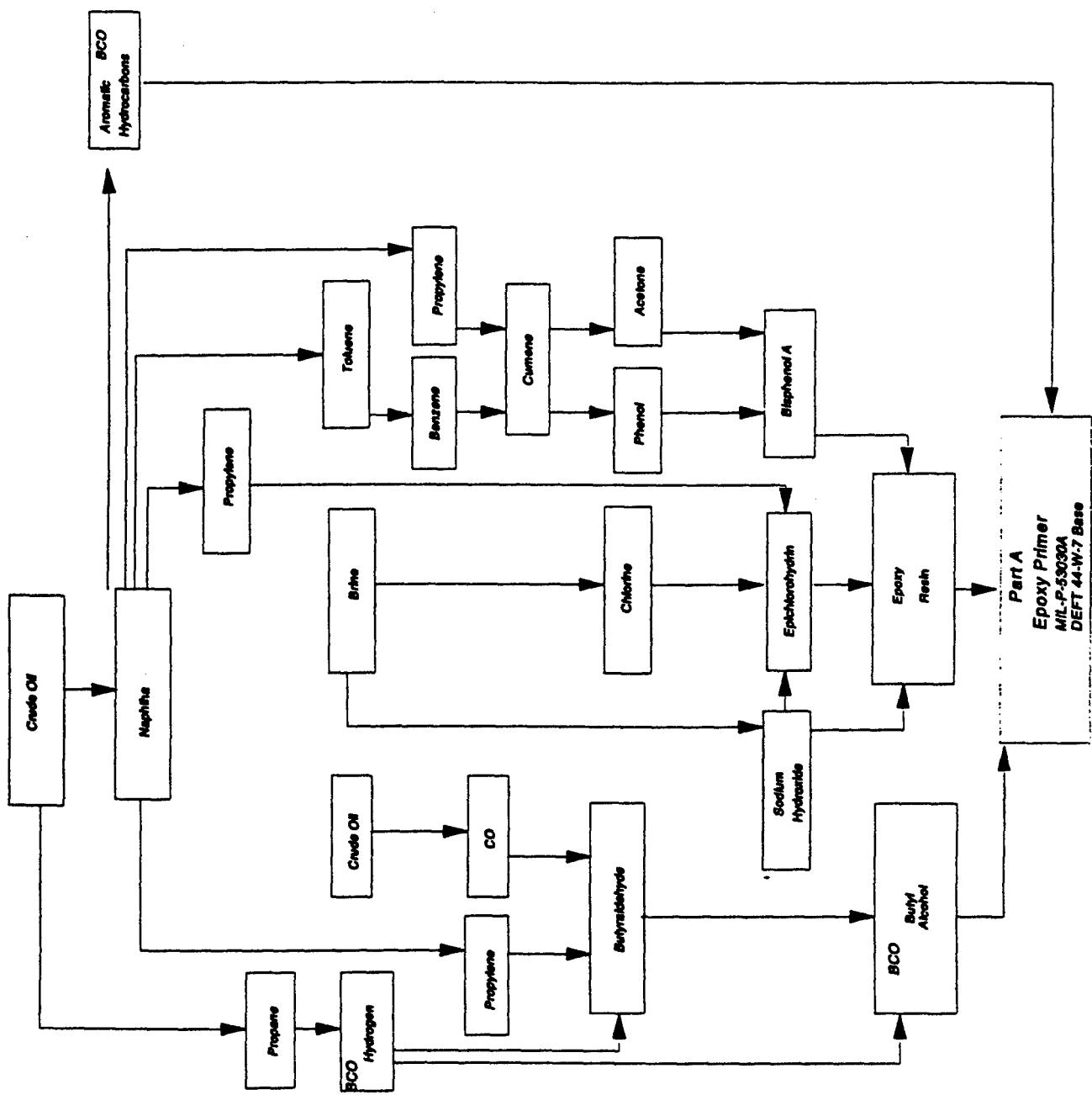
Figure A-2. Process flowsheet for Part A, baseline primer



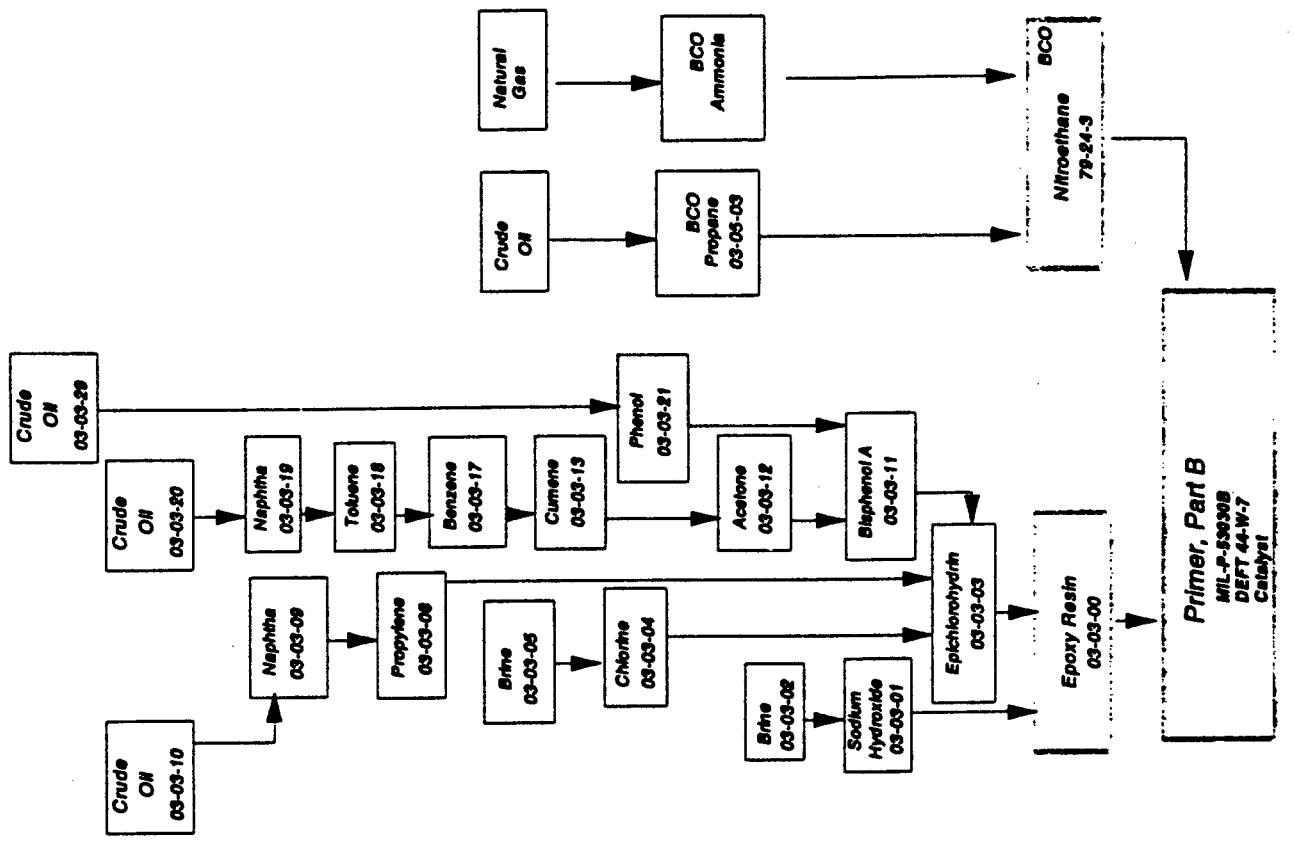
**Figure A-3. Process flowsheet for Part B, baseline primer**



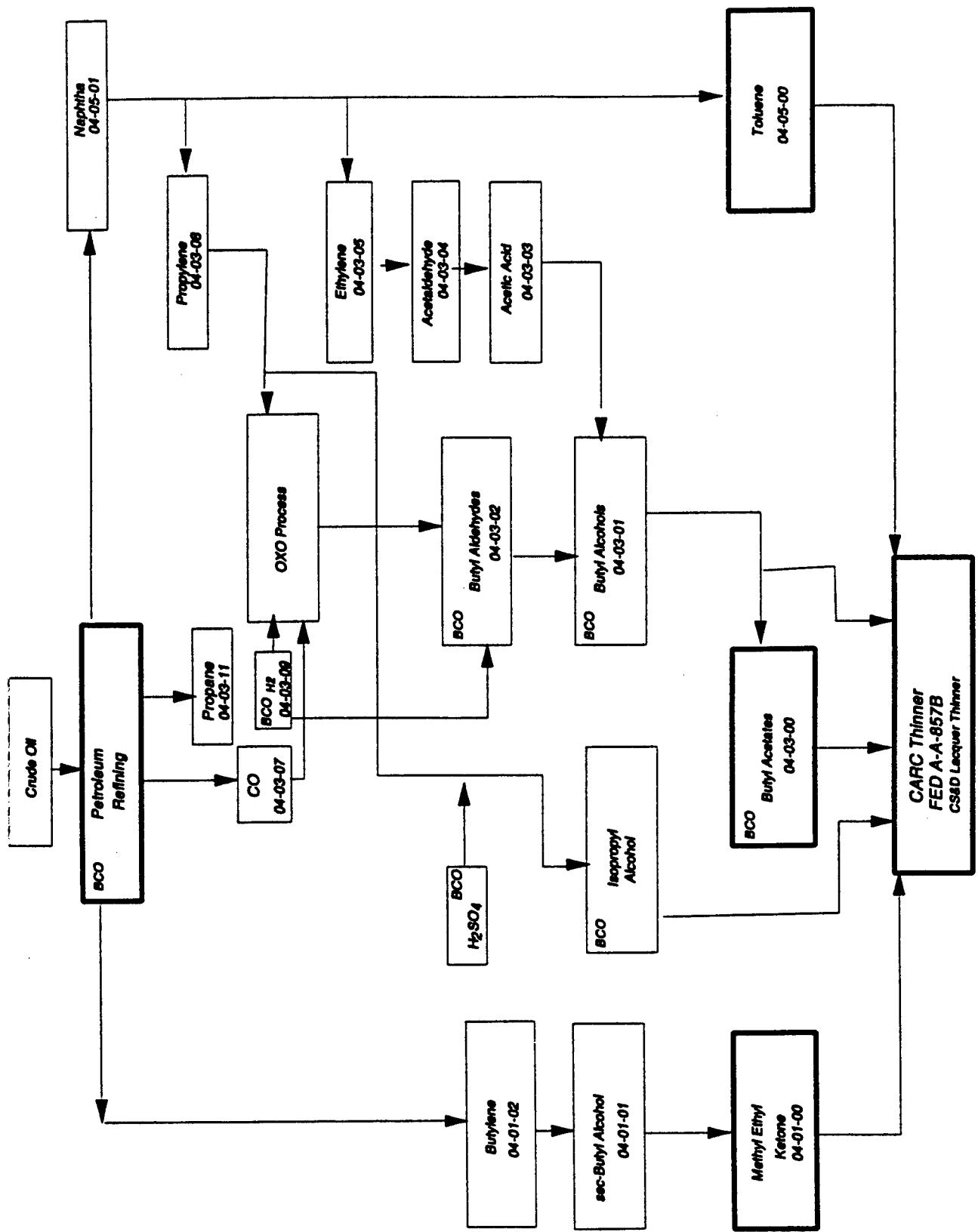
**Figure A-4. Process flowsheet for baseline thinner**



**Figure A-5. Process Flowsheet for Part A, Alternative Primer  
(BCO=data obtained by Battelle Columbus Operations; all other data from PES)**



**Figure A-6. Process Flowsheet for Part B, Alternative Primer**  
**(BCO=Data obtained by Battelle Columbus Operations; all other data from PES)**



**Figure A-7. Process Flowsheet for Alternative Thinner**  
**(BCO=data obtained by Battelle Columbus Operations; all other data from PES)**

APPENDIX B  
MATERIAL SAFETY DATA SHEETS (MSDSs)

CARC PAINT

MATERIAL SAFETY DATA SHEET  
FOR COATINGS, RESINS AND RELATED MATERIALS

Prepared By- JANE FREEMAN  
Date of Preparation- 04-26-93  
Manufacturer: Hentzen Coatings, Inc.  
Address : 6937 West Mill Road  
Milwaukee, Wisconsin 53218

Telephone #: (414)353-4200 Night: Not Available  
Emergency #: (414)353-4200 Night: (800)424-9300 (Chemtrec)  
\*\*\*\*\*

SECTION I -- PRODUCT IDENTIFICATION

-----

Manufacturer's Code Identification: 08605GUZ Contract #GS-10F-52323  
Product Class: ALIPHATIC POLYISOCYANATE NSN 1010-01-229-7547  
Trade Name: 383 GREEN ZENTHANE, MIL-C-53039A  
-----

HMIS Information: Health- 2 Flammability- 3  
Reactivity- 1 Personal Protective Equipment-

Hazardous Item per Fed. Std. 313C, Paragraph 3.33 : Yes  
\*\*\*\*\*

SECTION II -- HAZARDOUS INGREDIENTS

-----

METHYL ISOAMYL KETONE SOLVENT  
01 CAS# 110-12-3  
% BY WT: 23.787

EXPOSURE LIMIT:

ACGIH TLV/TWA	50 PPM
OSHA PEL	50 PPM
OTHER INFORMATION	RTECS #MP3950000

-----

MAGNESIUM-FERRITE PIGMENT  
02 CAS# 12068-86-9  
% BY WT: 1 - 5

EXPOSURE LIMIT:

ACGIH TLV/TWA	15 MG/M3
OSHA PEL	10 MG/M3
OTHER LIMITS	(NUISANCE DUST)
OTHER INFORMATION	NO RTECS # FOUND

-----

SILICA PIGMENT  
03 CAS# 14808-60-7  
% BY WT: 20 - 30

EXPOSURE LIMIT:

ACGIH TLV/TWA	0.1 MG/M3
OSHA PEL	0.1 MG/M3

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SECTION II -- HAZARDOUS INGREDIENTS

OTHER INFORMATION RTECS #VV7330000

HOMOPOLYMER OF HEXAMETHYLENE DIISOCYANATE

04  
% BY WT: 20 - 30 CAS# 28182-81-2

EXPOSURE LIMIT:

*EXACT PERCENTAGE:	EXACT PERCENTAGE IS A TRADE SECRET
ACGIH TLV/TWA	NOT ESTABLISHED
OSHA PEL	NOT ESTABLISHED
OTHER LIMITS	MFR.'S TWA = 0.5 MG/M3, STEL = 1.0 MG/M3
OTHER INFORMATION	NO RTECS # FOUND

TRIVALENT CHROME

05 (INSOLUBLE)  
% BY WT: 6.866 CAS# 7440-47-3

EXPOSURE LIMIT:

ACGIH TLV/TWA	0.5 MG/M3
OSHA PEL	0.5 MG/M3
OTHER INFORMATION	RTECS #GB4200000

INORGANIC SPINEL PIGMENT

06  
% BY WT: 1 - 5 CAS# NOT AVAIL.

EXPOSURE LIMIT:

ACGIH TLV/TWA	NOT ESTABLISHED
OSHA PEL	NOT ESTABLISHED
OTHER LIMITS	NOT LISTED BY OSHA OR ACGIH.
OTHER INFORMATION	NO RTECS # FOUND

AROMATIC HYDROCARBONS  
(MIXTURE OF C<sub>8</sub>'S TO C<sub>10</sub>'S)

07  
% BY WT: 1.498 CAS# 64742-95-6

EXPOSURE LIMIT:

ACGIH TLV/TWA	NOT ESTABLISHED
OSHA PEL	NOT ESTABLISHED
OTHER LIMITS	100 PPM = MFR.'S LIMIT
OTHER INFORMATION	NO RTECS # FOUND

BUTYL ACETATE SOLVENT

08  
% BY WT: 1.194 CAS# 123-86-4

EXPOSURE LIMIT:

ACGIH TLV/TWA	150 PPM
OSHA PEL	150 PPM

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SECTION II -- HAZARDOUS INGREDIENTS

OTHER LIMITS 200 PPM = STEL  
OTHER INFORMATION RTECS #AF7350000

HEXAMETHYLENE DIISOCYANATE MONOMER

09

% BY WT: 0.048

CAS# 822-06-0

EXPOSURE LIMIT:

ACGIH TLV/TWA 0.005 PPM  
OSHA PEL 0.005 PPM  
OTHER INFORMATION RTECS #MO1740000

VM&P NAPHTHA SOLVENT

10

% BY WT: 4.795

CAS# 64742-89-8

EXPOSURE LIMIT:

ACGIH TLV/TWA 300 PPM  
OSHA PEL 300 PPM  
OTHER INFORMATION RTECS #SE7555000

XYLENE SOLVENT

11

% BY WT: 2.040

CAS# 1330-20-7

EXPOSURE LIMIT:

ACGIH TLV/TWA 100 PPM  
OSHA PEL 100 PPM  
OTHER LIMITS STEL = 150 PPM  
OTHER INFORMATION RTECS #ZE210G000

This product contains no known carcinogens that are reportable.

SECTION III -- PHYSICAL DATA

Boiling Range: High- 416.0 F (214°C) Low- 144.0 F (118°C)

Vapor Pressure: 15.00 mm Hg at 65 F

Vapor Density: Heavier Than Air

Evaporation Rate: Faster than Butyl Acetate

Weight per Gallon: 10.29;

Specific Gravity: 1.23

% Nonexempt Solvent by Volume: 51.53

% Nonexempt Solvent by Weight: 33.94

VOC: 3.488 Lbs/Gal 418.542 Grams/Liter

Appearance: Opaque Liquid

--

Odor: Solvent Odor

Odor Threshold: 0.1 PPM

pH: Not Applicable

Viscosity: 65 - 68 Krebs Units

\*\*\*\*\* HENTZEN COATINGS, INC.

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Freezing Point: Not Available

Water Solubility: REACTS WITH WATER

Coefficient of Water/Oil Distribution: Not Available

SECTION IV -- FIRE AND EXPLOSION HAZARD DATA

Flammability Classification: Class 1B DOT: Flammable Liquid

Actual Flashpoint TCC: 54.0 F.(12°C)

Explosion Level: Lower- 0.9 Upper- 8.2

Auto Ignition Temperature: 450.0 F (232°C)

Decomposition Temperature: 400F (204C)

Melting point: Not Applicable

Magnetism & Corrosion Rate: Not Applicable

EXTINGUISHING MEDIA: ( X )-FOAM ( X )-ALCOHOL FOAM ( X )-CO<sub>2</sub>

( X )-DRY CHEMICAL ( )-WATER FOG ( )-OTHEE

UNUSUAL FIRE AND EXPLOSION HAZARDS: Keep containers tightly closed.

Isolate from heat, electrical equipment, sparks and open flame. Closed container may explode when exposed to extreme heat or burst when contaminated with water (CO<sub>2</sub> evolved). Do not apply to hot surfaces. Never use welding or cutting torch on or near drum (even empty) because product (even residue) can ignite explosively.

SPECIAL FIRE FIGHTING PROCEDURES: Full protective equipment with self-contained breathing apparatus should be worn. During a fire, irritating and highly toxic gases (see Reactivity Data) and smoke are present from the decomposition/combustion products.

SECTION V -- REACTIVITY DATA

NEUTRALIZING AGENT: 0% - 10% Ammonium Hydroxide, 2% - 5% Detergent and the balance is water; or a solution of NIACT Corp.'s Tergitol TMN-10 (20%) and water (80%).

STABILITY: ( ) - UNSTABLE ( X ) - STABLE

HAZARDOUS POLYMERIZATION ( ) - WILL OCCUR ( X ) - WILL NOT OCCUR

HAZARDOUS DECOMPOSITION PRODUCTS: BY FIRE: CO<sub>2</sub>, CO, oxides of Nitrogen, traces of Hydrogen Cyanide, Hexamethylene Diisocyanate.

CONDITIONS TO AVOID: Contamination with water, epoxy catalysts, alcohols, glycol ethers, bases, metal complexes or other active materials.

Once the material has been exposed to any of the above or atmospheric moisture, do not seal container as hazardous CO<sub>2</sub> gas could build up in the container resulting in rapid depressurization.

INCOMPATIBILITY: See CONDITIONS TO AVOID.

SECTION VI -- HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE:

TO VAPOR AND/OR MIST: Can cause irritation to skin, eyes and respiratory tract (nose, throat, lungs). Symptoms may be watering eyes, dryness of throat, coughing, headache, tightness in chest or burning sensation. Headache, dizziness or nausea may be experienced by some as a result of exposure to solvents.

PRIMARY ROUTES OF ENTRY: DERMAL and INHALATION

HENTZEN COATINGS, INC.

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system damage, liver and kidney damage.

Chronic overexposure to isocyanate containing products may lead to respiratory sensitization characterized by asthma-like symptoms and/or skin sensitization characterized by allergic dermatitis which may include rash, itching, hives and swelling of the extremities.

Based upon laboratory animal data, IARC has listed Silica as a "Probable Human Carcinogen". May cause lung injury if respiratory protection is not used.

Some reports have associated repeated and prolonged contact with Trivalent Chrome to dermatitis. Avoid contact with eyes, skin and clothing. Wash thoroughly after handling.

EMERGENCY AND FIRST AID PROCEDURES: INHALATION: Remove from exposure. Restore breathing. Keep warm and quiet. Notify a physician.

EYES: Flush immediately with large amounts of running water for at least 15 minutes while lifting eyelids. Take to a physician for treatment.

SKIN: Wash affected areas with soap and water. Remove contaminated clothing. Wash before reuse. Consult a physician if irritation develops or persists.

INGESTION: If swallowed, CALL A PHYSICIAN OR POISON CONTROL CENTER IMMEDIATELY.

MEDICAL CONDITIONS PRONE TO AGGRAVATION BY EXPOSURE: Asthma and other respiratory ailments; chemical sensitization.

SECTION VII -- PRECAUTIONS FOR SAFE HANDLING AND USE

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED: Evacuate non-essential personnel. Remove all sources of ignition (flames, hot surfaces, electrical, static or frictional sparks). Ventilate area. Avoid breathing vapors. Cover spill with inert absorbent. Pour liquid decontaminant over spillage--allow to react for at least 10 minutes; collect material in open containers--add further amounts of decontamination solution. Remove containers to safe place--cover loosely. Wash down area with decontaminant and flush spill area with water.

WASTE DISPOSAL METHODS: Dispose of in accordance with local, state and Federal regulations. Decontaminate containers prior to disposal.

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING: Do not store above 120 F or below 32 F. Store large quantities in buildings designed to comply with OSHA 1910.105. Keep away from sparks and open flame. Keep containers tightly closed and protect from moisture. If moisture enters container, pressure can build up due to reaction producing CO<sub>2</sub> which can cause sealed container to pressurize and burst. Do not reseal if contamination is suspected.

OTHER PRECAUTIONS: Do not take internally. Containers should be grounded when pouring. Avoid free fall of liquid in excess of a few inches. Use with adequate ventilation and respiratory equipment. Emptied containers may retain hazardous residue or explosive vapors. Follow all precautions in this data sheet until container is thoroughly cleaned or destroyed.

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SECTION VIII -- CONTROL MEASURES

**RESPIRATORY PROTECTION:** The Surgeon General requires airline respirators to be used unless air sampling shows exposure to be below OSHA limits. Then, either chemical cartridge respirators or airline respirators are required. The same precautions should be used during mixing or any operations where paint fumes would be present.

**VENTILATION:** Provide general dilution or local exhaust ventilation in volume and pattern to keep the air contaminant concentration below current applicable OSHA safety and health requirements in the mixing, application and curing areas; and to remove decomposition products during welding and flame cutting on surfaces coated with this product.

**PROTECTIVE GLOVES:** Chemical resistant gloves.

**EYE PROTECTION:** Use safety eyewear with splash guards and side shields.

**OTHER PROTECTIVE EQUIPMENT:** Wear protective clothing to keep skin contact at a minimum.

**HYGIENIC PRACTICES:** Wash hands and any exposed skin thoroughly before eating or smoking. Smoke in designated areas only.

SECTION IX -- TRANSPORTATION

**APPLICABLE REGULATION:** 49 CFR 171      **SHIPPING NAME:** PAINT  
**ID #:** UN1263      **REPORTABLE QUANTITY:** 100 lbs.      **HAZARD CLASS:** 3  
**LABEL:** FLAMMABLE LIQUID      **UNIT CONTAINER:** CN (Five Gallons)

**DOT SPECIFICATION CONTAINER:** 24 Gauge Steel

**DOT EXEMPTION:** NONE

**LIMITED QUANTITY:** YES

**U.S. POSTAL SERVICE:** Will not handle

**NET EXPLOSIVE WEIGHT:** Not Applicable

**AEROSOL PROPELLANTS:** Not Applicable

**DISPOSAL INFORMATION:**

**EPA HAZARDOUS WASTE NUMBER/CODE:** D001

**HAZARDOUS WASTE CHARACTERISTICS:** Ignitable

**DISPOSAL METHODS:** Incineration

SECTION X -- SECTION 313 TOXIC CHEMICALS

This product contains the following toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 and of 40 CFR 372:

Chemical	CAS Number	Weight %
TRIVALENT CHROME	7440-47-3	6.866
XYLENE SOLVENT	1330-20-7	2.040

HENTZEN COATINGS, INC.  
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FROM OUR RAW MATERIAL SUPPLIERS AND OTHER SOURCES AND  
IS BELIEVED TO BE RELIABLE. THIS DATA IS NOT TO BE TAKEN  
AS A WARRANTY OR REPRESENTATION FOR WHICH HENTZEN COATINGS,  
INC. ASSUMES LEGAL RESPONSIBILITY.

DOD Hazardous Materials Information System  
DoD 6050.5-L  
AS OF April 1995

FSC: 8010  
NIIN: 00D002882  
Manufacturer's CAGE: 02388  
Part No. Indicator: A  
Part Number/Trade Name: N-1088A WHITE EPOXY PRIMER

Primer Part A

General Information

Item Name: WHITE EPOXY PRIMER  
Manufacturer's Name: NILES CHEMICAL PAINT CO.  
Manufacturer's Street: 225 FORT STREET  
Manufacturer's P. O. Box: 307  
Manufacturer's City: NILES  
Manufacturer's State: MI  
Manufacturer's Country: US  
Manufacturer's Zip Code: 49120  
Manufacturer's Emerg Ph #: 800-627-1948, 219-236-5856  
Manufacturer's Info Ph #: 616-683-3377  
Distributor/Vendor # 1:  
Distributor/Vendor # 1 Cage:  
Distributor/Vendor # 2:  
Distributor/Vendor # 2 Cage:  
Distributor/Vendor # 3:  
Distributor/Vendor # 3 Cage:  
Distributor/Vendor # 4:  
Distributor/Vendor # 4 Cage:  
Safety Data Action Code:  
Safety Focal Point: G  
Record No. For Safety Entry: 001  
Tot Safety Entries This Stk#: 001  
Status: SE  
Date MSDS Prepared: 23AUG92  
Safety Data Review Date: 29OCT92  
Supply Item Manager: GSA  
MSDS Preparer's Name: MIKE LICHATOWICH  
Preparer's Company:  
Preparer's St Or P. O. Box:  
Preparer's City:  
Preparer's State:  
Preparer's Zip Code:  
Other MSDS Number:  
MSDS Serial Number: BPCGR  
Specification Number: MIL-P-53022B  
Spec Type, Grade, Class:  
Hazard Characteristic Code: F3  
Unit Of Issue: EA  
Unit Of Issue Container Qty: UNKNOWN  
Type Of Container: UNKNOWN  
Net Unit Weight: UNKNOWN

Report for NIIN: 00D002882

NRC/State License Number: N/R  
Net Explosive Weight:  
Net Propellant Weight-Ammo: N/R  
Coast Guard Ammunition Code:

-----  
Ingredients/Identity Information  
-----

Proprietary: NO  
Ingredient: N-BUTYL ACETATE (SARA III)  
Ingredient Sequence Number: 01  
Percent: 26  
Ingredient Action Code:  
Ingredient Focal Point: G  
NIOSH (RTECS) Number: AF7350000  
CAS Number: 123-86-4  
OSHA PEL: 150 PPM/200 STEL  
ACGIH TLV: 150 PPM/200STEL;9192  
Other Recommended Limit: NONE SPECIFIED

-----  
Proprietary: NO  
Ingredient: EPOXY RESIN  
Ingredient Sequence Number: 02  
Percent: 22  
Ingredient Action Code:  
Ingredient Focal Point: G  
NIOSH (RTECS) Number: 1000131ER  
CAS Number: 25036-25-3  
OSHA PEL: NOT ESTABLISHED  
ACGIH TLV: NOT ESTABLISHED  
Other Recommended Limit: 5 MG/M3 TLV

-----  
Proprietary: NO  
Ingredient: N-BUTYL ALCOHOL (SARA III)  
Ingredient Sequence Number: 03  
Percent: 8  
Ingredient Action Code:  
Ingredient Focal Point: G  
NIOSH (RTECS) Number: EO1400000  
CAS Number: 71-36-3  
OSHA PEL: 100 PPM  
ACGIH TLV: S, C 50 PPM; 9293  
Other Recommended Limit: NONE SPECIFIED

-----  
Proprietary: NO  
Ingredient: ZINC PHOSPHATE  
Ingredient Sequence Number: 04  
Percent: 4  
Ingredient Action Code:  
Ingredient Focal Point: G  
NIOSH (RTECS) Number: 1001478ZP  
CAS Number: UNKNOWN  
OSHA PEL: NOT ESTABLISHED  
GIH TLV: NOT ESTABLISHED

Report for NIIN: 00D002882

Other Recommended Limit: NONE SPECIFIED

Proprietary: NO

Ingredient: METHYL ISOBUTYL KETONE (SARA III)

Ingredient Sequence Number: 05

Percent: 2

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: SA9275000

CAS Number: 108-10-1

OSHA PEL: 100 PPM/75 STEL

ACGIH TLV: 50 PPM/75 STEL; 9293

Other Recommended Limit: NONE SPECIFIED

Proprietary: NO

Ingredient: PROPRIETARY INGREDIENTS

Ingredient Sequence Number: 06

Percent: BALANCE

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: 1004255PI

CAS Number: UNKNOWN

OSHA PEL: NOT ESTABLISHED

ACGIH TLV: NOT ESTABLISHED

Other Recommended Limit: NONE SPECIFIED

#### Physical/Chemical Characteristics

Appearance And Odor: LIQUID, ODOR OF SOLVENTS.

Boiling Point: 242F, 117C

Melting Point: UNKNOWN

Vapor Pressure (MM Hg/70 F): UNKNOWN

Vapor Density (Air=1): > AIR

Specific Gravity: 1.347

Decomposition Temperature: UNKNOWN

Evaporation Rate And Ref: SLOWER THAN ETHER

Solubility In Water: SLIGHT

Percent Volatiles By Volume: 59.63

Viscosity:

pH: N/K

Radioactivity:

Form (Radioactive Matl):

Magnetism (Milligauss):

Corrosion Rate (IPY): MINIMAL

Autoignition Temperature:

#### Fire and Explosion Hazard Data

Flash Point: 72.0F, 22.2C

Flash Point Method: TCC

Lower Explosive Limit: 1.4

Upper Explosive Limit: 11.0

Extinguishing Media: DRY CHEMICAL, FOAM, CARBON DIOXIDE.

Report for NIIN: 00D002882

Special Fire Fighting Proc: WEAR SCA WITH FULL FACEPIECE IN POSITIVE DRESS MODE/FULL PROTECT CLOTHES. USE H<sub>2</sub>O TO COOL CLOSED CONTAINERS TO PREVENT PRESS BUILDUP, AUTOIGNITION, EXPLOSION.

Unusual Fire And Expl Hazrds: VAPORS ARE HEAVIER THAN AIR AND MAY TRAVEL ALONG GROUND TO IGNITION SOURCE. CLOSED CONTAINERS MAY EXPLODE WHEN EXPOSED TO EXTREME HEAT.

#### Reactivity Data

Stability: YES

Cond To Avoid (Stability): MATERIAL IS STABLE UNDER REASONABLE CONDITIONS OF STORAGE AND USE. AVOID HIGH TEMPERATURES AND SHOCK FROM DROPPING.

Materials To Avoid: NITRATES, STRONG OXIZIDERS, ALKALIS, ACIDS.

Hazardous Decomp Products: CAN PRODUCE CARBON MONOXIDE AND/OR CARBON DIOXIDE.

Hazardous Poly Occur: NO

Conditions To Avoid (Poly): WILL NOT OCCUR.

#### Health Hazard Data

LD50-LC50 Mixture: UNKNOWN

Route Of Entry - Inhalation: YES

Route Of Entry - Skin: YES

Route Of Entry - Ingestion: YES

Health Haz Acute And Chronic: EYES: SEVERE IRRITATION, BLURRED VISION.

SKIN: HARMFULL IF ABSORBED THROUGH SKIN. CAN BE ABSORBED IN TOXIC AMOUNTS FROM PROLONGED EXPOSURES. INHALATION: NASAL AND RESPIRATORY IRRITATION, CNS DEPRESSION, NAUSEA, UNCONSCIOUSNESS, ASPHYXIATION. INGESTION: GI IRRITATION, ABDOMINAL PAIN, NAUSEA, VOMITING, DIARRHEA.

Carcinogenicity - NTP: NO

Carcinogenicity - IARC: NO

Carcinogenicity - OSHA: NO

Explanation Carcinogenicity: NOT LISTED BY NTP, IARC, OSHA.

Signs/Symptoms Of Overexp: EYES: SEVERE IRRITATION. TEARING, REDNESS, BLURRED VISION. INHALATION: NASAL AND RESPIRATORY IRRITATION, CNS DEPRESSION, DIZZINESS, DROWSINESS, WEAKNESS, FATIGUE, CONFUSION, NAUSEA, HEADACHE, VERTIGO. POSSIBLE UNCONSCIOUSNESS, EVEN ASPHYXIATION. INGESTION: GI IRRITATION, ABDOMINAL PAIN, NAUSEA, VOMITING, DIARRHEA.

Med Cond Aggravated By Exp: NONE KNOWN.

Emergency/First Aid Proc: EYES: FLUSH WITH LARGE AMOUNTS OF WATER. GET MEDICAL ATTENTION. SKIN: REMOVE CONTAMINATED CLOTHING. FLUSH AREA WITH LARGE AMOUNTS OF WATER. INHALATION: MOVE TO FRESH AIR. IF NOT BREATHING GIVE CPR. GET MEDICAL ATTENTION. INGESTION: DRINK 1 OR 2 GLASSES OF WATER. DO NOT INDUCE VOMITING. GET MEDICAL ATTENTION.

#### Precautions for Safe Handling and Use

Steps If Matl Released/Spill: ELIMINATE ALL IGNIT SOURCES. ABSORB WITH INERT MATERIAL SUCH AS CLAY, SOIL OR A COMMERCIALLY AVAILABLE ABSORBENT. SHOVEL RECLAIMED LIQUID/ABSORBENT INTO RECOVERY/SALVAGE DRUM OR TANK TRUCK FOR DISPOSAL. DIKE LARGE SPILLS TO PREVENT RUNOFF.

Neutralizing Agent: NONE SPECIFIED BY MANUFACTURER.

Waste Disposal Method: DISPOSE OF WASTE IN ACCORDANCE WITH APPLICABLE

Report for NIIN: 00D002882

LOCAL, STATE AND FEDERAL REGULATIONS.

Precautions-Handling/Storing: AVOID STORAGE IN HIGH TEMPERATURE AREAS OR NEAR FIRE OR OPEN FLAME. KEEP CONTAINERS CLOSED. AVOID ROUGH HANDLING AND PROTECT FROM PHYSICAL DAMAGE.

Other Precautions: CONTAINERS OF THIS MATERIAL MAY BE HAZARDOUS WHEN EMPTY. DO NOT WELD OR FLAME CUT ON EMPTY DRUMS.

Control Measures

Respiratory Protection: WEAR APPROPRIATE PROPERLY FITTED HALF-MASK/FULL FACEPIECE RESPIRATOR DURING AND AFTER APPLICATION UNLESS AIR MONITORING DEMONSTRATES VAPOR/MIST LEVELS ARE BELOW APPLICABLE LIMITS . FOLLOW RESPIRATOR MANUFACTURER'S DIRECTIONS FOR USE.

Ventilation: SUFFICIENT VENTILATION TO KEEP AIR CONCENTRATION BELOW PERMISSIBLE EXPOSURE LIMITS. VENT VAPOURS WHEN BAKING FINISHES.

Protective Gloves: NITRILE OR VITON GLOVES

Eye Protection: CHEM GOGGLES, SAFETY GLASSES, FACESHIELD.

Other Protective Equipment: NITRILE OR VITON CLOTHING AS NEEDED TO PREVENT SKIN CONTACT.

Work Hygienic Practices: WASH AFTER HANDLING AND BEFORE EATING, DRINKING, SMOKING, OR USING RESTROOM. LAUNDER CONTAMINATED CLOTHING BEFORE REUSE.

Suppl. Safety & Health Data: CONTACT LENSES SHOULD NOT BE WORN WHEN WORKING WITH THIS MATERIAL.

DOD Hazardous Materials Information System  
DOD 6050.5-L  
AS OF April 1995

FSC: 8010  
NIIN: 00D002883  
Manufacturer's CAGE: 02388  
Part No. Indicator: A  
Part Number/Trade Name: N-1088BM 4:1 BLEND

Primer Part B

===== General Information =====

Item Name: ENAMEL, EPOXY, YELLOW  
Manufacturer's Name: NILES CHEMICAL PAINT CO.  
Manufacturer's Street: 225 PORT STREET  
Manufacturer's P. O. Box: 307  
Manufacturer's City: NILES  
Manufacturer's State: MI  
Manufacturer's Country: US  
Manufacturer's Zip Code: 49120  
Manufacturer's Emerg Ph #: 800-627-1948, 219-236-5656  
Manufacturer's Info Ph #: 616-683-3377

Distributor/Vendor # 1:  
Distributor/Vendor # 1 Cage:  
Distributor/Vendor # 2:  
Distributor/Vendor # 2 Cage:  
Distributor/Vendor # 3:  
Distributor/Vendor # 3 Cage:  
Distributor/Vendor # 4:  
Distributor/Vendor # 4 Cage:

Safety Data Action Code:  
Safety Focal Point: G

Record No. For Safety Entry: 001

Tot Safety Entries This Stk#: 001

Status: SE

Date MSDS Prepared: 23SEP92

Safety Data Review Date: 28OCT92

Supply Item Manager: GSA

MSDS Preparer's Name: MIKE LICHATOWICH

Preparer's Company:

Preparer's St Or P. O. Box:

Preparer's City:

Preparer's State:

Preparer's Zip Code:

Other MSDS Number:

MSDS Serial Number: BPCGS

Specification Number: MIL-P-53022B

Spec Type, Grade, Class:

Hazard Characteristic Code: F4

Unit Of Issue: EA

Unit Of Issue Container Qty: UNKNOWN

Type Of Container: UNKNOWN

Net Unit Weight: UNKNOWN

Report for NIIN: 00D002893

NRC/State License Number: N/R

Net Explosive Weight:

Net Propellant Weight-Ammo: N/R

Coast Guard Ammunition Code:

=====

Ingredients/Identity Information

=====

Proprietary: NO

Ingredient: METHYL ISOBUTYL KETONE (SARA III)

Ingredient Sequence Number: 01

Percent: 28

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: SA9275000

CAS Number: 108-10-1

OSHA PEL: 100 PPM/75 STEL

ACGIH TLV: 50 PPM/75 STEL; 9293

Other Recommended Limit: NONE SPECIFIED

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Proprietary: NO

Ingredient: EPOXY RESIN

Ingredient Sequence Number: 02

Percent: 23

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: 1000131ER

CAS Number: UNKNOWN

OSHA PEL: NOT ESTABLISHED

ACGIH TLV: NOT ESTABLISHED

Other Recommended Limit: NONE SPECIFIED

-----

Proprietary: NO

Ingredient: N-BUTYL ALCOHOL (SARA III)

Ingredient Sequence Number: 03

Percent: 17

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: E01400000

CAS Number: 71-36-3

OSHA PEL: 100 PPM

ACGIH TLV: S, C 50 PPM; 9293

Other Recommended Limit: NONE SPECIFIED

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Proprietary: NO

Ingredient: 2-ETHOXYETHANOL (EGEE) (SARA III)

Ingredient Sequence Number: 04

Percent: 11

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: KK8050000

CAS Number: 110-80-5

OSHA PEL: S, 200 PPM

GIH TLV: S, 5 PPM; 9192

Report for NIIN: 00D002883

Other Recommended Limit: NONE SPECIFIED

Proprietary: NO

Ingredient: XYLENES (O-,M-,P- ISOMERS) (SARA III)

Ingredient Sequence Number: 05

Percent: 11

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: ZE2100000

CAS Number: 1330-20-7

OSHA PEL: 100 PPM/150 STEL

ACGIH TLV: 100 PPM/150STEL; 9192

Other Recommended Limit: NONE SPECIFIED

Proprietary: NO

Ingredient: DIETHYLENE TRIAMINE

Ingredient Sequence Number: 06

Percent: 8

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: IE1225000

CAS Number: 111-40-0

OSHA PEL: 1 PPM

ACGIH TLV: S, 1 PPM; 9192

Other Recommended Limit: NONE SPECIFIED

Proprietary: NO

Ingredient: PROPRIETARY INGREDIENTS

Ingredient Sequence Number: 07

Percent: BALANCE

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: 1004255PI

CAS Number: UNKNOWN

OSHA PEL: NOT ESTABLISHED

ACGIH TLV: NOT ESTABLISHED

Other Recommended Limit: NONE SPECIFIED

#### Physical/Chemical Characteristics

Appearance And Odor: LIQUID, ODOR OF SOLVENTS

Boiling Point: 242F, 117C

Melting Point: UNKNOWN

Vapor Pressure (MM Hg/70 F): UNKNOWN

Vapor Density (Air=1): > AIR

Specific Gravity: 0.905

Decomposition Temperature: UNKNOWN

Evaporation Rate And Ref: SLOWER THAN ETHER

Solubility In Water: SLIGHT

Percent Volatiles By Volume: 74.70

Viscosity:

pH: N/K

Radioactivity:

Report for NIIN: 00D002883

Form (Radioactive Matl):

Magnetism (Milligauss):

Corrosion Rate (IPY): MINIMAL

Autoignition Temperature:

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Fire and Explosion Hazard Data  
=====

Flash Point: 73.0F, 22.8C

Flash Point Method: TCC

Lower Explosive Limit: 1.0

Upper Explosive Limit: 14

Extinguishing Media: DRY CHEMICAL, FOAM, CO<sub>2</sub>

Special Fire Fighting Proc: WEAR SCBA WITH FULL FACEPIECE IN POS PRESS MODE/FULL PROTECT CLOTHES. USE H<sub>2</sub>O TO COOL CLOSED CONTAINERS TO PREVENT PRESS BUILDUP AND AUTOIGNITION OR EXPLOSION.

Unusual Fire And Expl Hazrds: VAPORS ARE HEAVIER THAN AIR AND MAY TRAVEL ALONG GROUND TO IGNITION SOURCE. ISOLATE FROM HEAT, IGNITION SOURCES. APPLICATION TO HOT SURFACES NEED SPECIAL CARE.

=====  
Reactivity Data  
=====

Stability: YES

Cond To Avoid (Stability): HIGH TEMPERATURES, IGNITION SOURCES. SHOCK FROM DROPPING.

Materials To Avoid: STRONG OXIDIZERS

Hazardous Decomp Products: CAN PRODUCE CARBON MONOXIDE AND/OR CARBON DIOXIDE.

Hazardous Poly Occur: NO

Conditions To Avoid (Poly): WILL NOT OCCUR.

=====  
Health Hazard Data  
=====

LD50-LC50 Mixture: UNKNOWN

Route Of Entry - Inhalation: YES

Route Of Entry - Skin: YES

Route Of Entry - Ingestion: YES

Health Haz Acute And Chronic: EYES: SEVERE IRRITATION, BLURRED VISION.

SKIN: HARMFULL IF ABSORBED THROUGH SKIN. CAN BE ABSORBED IN TOXIC AMOUNTS FROM PROLONGED EXPOSURES. INHALATION: NASAL AND RESPIRATORY IRRITATION, CNS DEPRESSION, NAUSEA, UNCONSCIOUSNESS, ASPHYXIATION. INGESTION: GI IRRITATION, ABDOMINAL PAIN, NAUSEA, VOMITING, DIARRHEA.

Carcinogenicity - NTP: NO

Carcinogenicity - IARC: NO

Carcinogenicity - OSHA: NO

Explanation Carcinogenicity: NOT LISTED BY NTP, IARC, OR OSHA.

Signs/Symptoms Of Overexp: EYES: SEVERE IRRITATION, TEARING, REDNESS, BLURRED VISION. INHALATION: NASAL AND RESPIRATORY IRRITATION, CNS DEPRESSION, DIZZINESS, DROWSINESS, WEAKNESS, FATIGUE, CONFUSION, NAUSEA, HEADACHE, VERTIGO. POSSIBLE UNCONSCIOUSNESS, EVEN ASPHYXIATION. INGESTION: GI IRRITATION, ABDOMINAL PAIN, NAUSEA, VOMITING, DIARRHEA.

Med Cond Aggravated By Exp: NONE KNOWN.

Emergency/First Aid Proc: EYES: FLUSH WITH LARGE AMOUNTS OF WATER. GET MEDICAL ATTENTION. SKIN: REMOVE CONTAMINATED CLOTHING. FLUSH AREA WITH

Report for NIIN: 00D002883

LARGE AMOUNTS OF WATER. INHALATION: MOVE TO FRESH AIR. IF NOT BREATHING GIVE CPR. GET MEDICAL ATTENTION. INGESTION: DRINK 1 OR 2 GLASSES OF WATER. DO NOT INDUCE VOMITING. GET MEDICAL ATTENTION.

===== Precautions for Safe Handling and Use =====

Steps If Matl Released/Spill: ELIMINATE ALL IGNITION SOURCES. ABSORB WITH INERT MATERIAL SUCH AS CLAY, SOIL OR A COMMERCIALLY AVAILABLE ABSORBENT. SHOVEL RECLAIMED LIQUID/ABSORBENT INTO RECOVERY/SALVAGE DRUM OR TANK TRUCK FOR DISPOSAL. DIKE LARGE SPILLS TO PREVENT RUNOFF.

Neutralizing Agent: NONE SPECIFIED BY MANUFACTURER.

Waste Disposal Method: DISPOSE OF WASTE IN ACCORDANCE WITH APPLICABLE LOCAL, STATE AND FEDERAL REGULATIONS.

Precautions-Handling/Storing: AVOID STORAGE IN HIGH TEMPERATURE AREAS OR NEAR FIRE OR OPEN FLAME. KEEP CONTAINERS CLOSED. AVOID ROUGH HANDLING AND PROTECT FROM PHYSICAL DAMAGE.

Other Precautions: CONTAINERS OF THIS MATERIAL MAY BE HAZARDOUS WHEN EMPTY. DO NOT WELD OR FLAME CUT ON EMPTY DRUMS.

===== Control Measures =====

Respiratory Protection: WEAR APPROPRIATE PROPERLY FITTED HALF-MASK/FULL FACEPIECE RESPIRATOR DURING AND AFTER APPLICATION UNLESS AIR MONITORING DEMONSTRATES VAPOR/MIST LEVELS ARE BELOW APPLICABLE LIMITS. FOLLOW RESPIRATOR MANUFACTURER'S DIRECTIONS FOR USE.

Ventilation: SUFFICIENT VENTILATION TO KEEP AIR CONCENTRATION BELOW PERMISSIBLE EXPOSURE LIMITS. VENT VAPORS WHEN BAKING FINISHES.

Protective Gloves: NITRILE OR VITON GLOVES.

Eye Protection: CHEM GOGGLES, SAFETY GLASSES, FACESHIELD.

Other Protective Equipment: NITRILE OR VITON CLOTHING AS NEEDED TO PREVENT SKIN CONTACT.

Work Hygienic Practices: WASH AFTER HANDLING AND BEFORE EATING, DRINKING, SMOKING, OR USING RESTROOM. LAUNDER CONTAMINATED CLOTHING BEFORE REUSE.

Suppl. Safety & Health Data: CONTACT LENSES SHOULD NOT BE WORN WHEN WORKING WITH THIS MATERIAL.

DOD Hazardous Materials Information System  
DoD 6050.5-L  
AS OF April 1995

FSC: 8010

NIIN: 001818079

Manufacturer's CAGE: 5W216

Part No. Indicator: B

Part Number/Trade Name: THINNER AIRCRAFT COATING

===== General Information =====

Item Name: THINNER, AIRCRAFT COATING, POLYURETHANE \*

Manufacturer's Name: CHEMICAL SPECIALISTS & DEVELOPMENT \*

Manufacturer's Street: #5 HACKBERRY LANE \*

Manufacturer's P. O. Box: N/K \*

Manufacturer's City: CUT & SHOOT \*

Manufacturer's State: TX \*

Manufacturer's Country: US \*

Manufacturer's Zip Code: 77303 \*

Manufacturer's Emerg Ph #: 800-424-9300 \*

Manufacturer's Info Ph #: 409-756-1065 \*

Distributor/Vendor # 1:

Distributor/Vendor # 1 Cage:

Distributor/Vendor # 2:

Distributor/Vendor # 2 Cage:

Distributor/Vendor # 3:

Distributor/Vendor # 3 Cage:

Distributor/Vendor # 4:

Distributor/Vendor # 4 Cage:

Safety Data Action Code: C

Safety Focal Point: G

Record No. For Safety Entry: 008

Tot Safety Entries This Stk#: 010

Status: FM \*

Date MSDS Prepared: 01SEP90 \*

Safety Data Review Date: 03FEB94 \*

Supply Item Manager: GSA \*

MSDS Preparer's Name: DAVID SHIPP \*

Preparer's Company: CHEMICAL SPECIALISTS & DEVELOPMENT \*

Preparer's St Or P. O. Box: #5 HACKBERRY LANE \*

Preparer's City: CUT & SHOOT \*

Preparer's State: TX \*

Preparer's Zip Code: 77303 \*

Other MSDS Number:

MSDS Serial Number: BJZSK

Specification Number: MIL-T-81772B \* Baseline used in LCI

Spec Type, Grade, Class: TYPE I \*

Hazard Characteristic Code: F3 \*

Unit Of Issue: CN

Unit Of Issue Container Qty: 5 GAL CAN

Type Of Container: METAL

Net Unit Weight: N/K

Report for NIIN: 001818079

IRC/State License Number: N/K

Net Explosive Weight: N/K

Net Propellant Weight-Ammo: N/K

Coast Guard Ammunition Code: N/K

=====

Ingredients/Identity Information

=====

Proprietary: NO

Ingredient: METHYL ETHYL KETONE (2-BUTANONE) (MEK) (SARA III)

Ingredient Sequence Number: 01

Percent: 30.5

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: EL6475000

CAS Number: 78-93-3

OSHA PEL: 200 PPM/300 STEL

ACGIH TLV: 200 PPM/300STEL 9192

Other Recommended Limit: NONE SPECIFIED

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Proprietary: NO

Ingredient: HEXYL ACETATE MIXED ISOMERS

Ingredient Sequence Number: 02

Percent: 41.0

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: 1004009HA

CAS Number: 88230-35-7

OSHA PEL: N/K

ACGIH TLV: N/K

Other Recommended Limit: 50 PPM 8 HOUR TWA

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Proprietary: NO

Ingredient: TOLUENE (SARA III)

Ingredient Sequence Number: 03

Percent: 10.5

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: XS5250000

CAS Number: 108-88-3

OSHA PEL: 200 PPM/150 STEL

ACGIH TLV: 50 PPM; 9293

Other Recommended Limit: NONE SPECIFIED

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Proprietary: NO

Ingredient: N-BUTYL ACETATE (SARA III)

Ingredient Sequence Number: 04

Percent: 11.0

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: AF7350000

CAS Number: 123-86-4

OSHA PEL: 150 PPM/200 STEL

ACGIH TLV: 150 PPM/200STEL;9192

Report for NIIN: 001818079

Other Recommended Limit: NONE SPECIFIED

Proprietary: NO

Ingredient: XYLENES (O-,M-,P- ISOMERS) (SARA III)

Ingredient Sequence Number: 05

Percent: 7.0

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: ZE2100000

CAS Number: 1330-20-7

OSHA PEL: 100 PPM/150 STEL

ACGIH TLV: 100 PPM/150STEL;9192

Other Recommended Limit: NOT SPECIFIED

#### Physical/Chemical Characteristics

Appearance And Odor: CLEAR, LITTLE IF ANY COLOR; CHARACTERISTIC ODOR \*

Boiling Point: 179F, 82C \*

Melting Point: -20F, -29C \*

Vapor Pressure (MM Hg/70 F): 35.1 MMHG \*

Vapor Density (Air=1): 3.4 \*

Specific Gravity: 0.850 \*

Odecomposition Temperature: N/K \*

Evaporation Rate And Ref: SLOWER THAN ETHER \*

Solubility In Water: MODERATE \*

Percent Volatiles By Volume: 100 \*

Viscosity: N/K

pH: N/K \*

Radioactivity: N/K

Form (Radioactive Matl): N/K

Magnetism (Milligauss): N/K

Corrosion Rate (IPY): NONE \*

Autoignition Temperature: N/K

#### Fire and Explosion Hazard Data

Flash Point: 20 F/-6.7 C \*

Flash Point Method: N/K \*

Lower Explosive Limit: 1.0 \*

Upper Explosive Limit: N/K \*

Extinguishing Media: REGULAR FOAM OR CARBON DIOXIDE OR DRY CHEMICAL \*

Special Fire Fighting Proc: WEAR SELF CONTAINED BREATHING APPARATUS W/  
FULL FACEPIECE OPERATED IN POSITIVE PRESS DEMAND MODE. VAPOR MAY TRAVEL TO  
IGNITE SOURCES DISTANT FROM HANDLING POINT \*

Unusual Fire And Expl Hazrds: NEVER WELD, USE CUTTING TORCH ON OR NEAR  
DRUM(EVEN EMPTY) CAN IGNITE EXPLOSIVELY. ALL 5 GAL PAIL & LARGE METAL  
CONTAINERS GROUND/BOND WHEN TRANSFERING MATERIAL. \*

#### Reactivity Data

Stability: YES \*

Cond To Avoid (Stability): N/K \*

Materials To Avoid: AVOID CONTACT WITH STRONG OXIDIZING AGENTS \*

Report for NIIN: 001818079

Hazardous Decomp Products: MAY FORM TOXIC MATERIALS. CARBON DIOXIDE & CARBON MONOXIDE, VARIOUS HYDROCARBONS, ETC. \*

Hazardous Poly Occur: NO \*

Conditions To Avoid (Poly): N/K \*

#### ===== Health Hazard Data =====

LD50-LC50 Mixture: N/K \*

Route Of Entry - Inhalation: YES \*

Route Of Entry - Skin: YES \*

Route Of Entry - Ingestion: NO \*

Health Haz Acute And Chronic: OVEREXPOSURE MAY CAUSE CARDIAC ABNORMALITY & LIVER ABNORMALITY. ASPIRATION OF MATERIAL INTO THE LUNGS DUE TO VOMITING CAN CAUSE CHEMICAL PNEUMONITIS WHICH CAN BE FATAL. \*

Carcinogenicity - NTP: N/K \*

Carcinogenicity - IARC: N/K \*

Carcinogenicity - OSHA: N/K \*

Explanation Carcinogenicity: N/K \*

Signs/Symptoms Of Overexp: EYES:IRRIT, REDNESS, TEARING. SKIN:  
PROLONGED/REPEATED CONTACT CAN CAUSE MODERATE IRRIT, DEFATT, DERMATITIS.  
EXCESSIVE INHALE:NASAL & RESPIRATORY IRRIT, CENTRAL NERVOUS SYSTEM,  
DIZZINESS, WEAKNESS, FATIGUE, NAUSEA, HEADACHE & POSSIBLE UNCONSCIOUSNESS &  
EVEN DEATH. SWALLOW:GASTROINTESTINAL IRRIT, NAUSEA, VOMIT & DIARRHE \*

Med Cond Aggravated By Exp: N/K \*

Emergency/First Aid Proc: SKIN:THOROUGHLY WASH AREA W/SOAP & WATER. REMOVE CONTAM CLOTHES. LAUNDER CONTAM CLOTHES BEFORE REUSE. EYES:FLUSH WITH LARGE AMOUNTS OF WATER, LIFTING UPPER & LOWER LIDS, GET MED ATTN. SWALLOWED:DO NOT INDUCE VOMITING, KEEP PERSON WARM, QUIET & GET MEDICAL ATTENTION.  
BREATH:REMOVE PERSON TO FRESH AIR. IF BREATH IS DIFF ADMIN OXYGEN. BREATH HAS STOPPED GIVE CPR. KEEP PERSON WARM, QUIET, GET MED ATTN \*

#### ===== Precautions for Safe Handling and Use =====

Steps If Matl Released/Spill: SM:ABSORB LIQ ON PAPER, VERMICULITE, FLOOR ABSORBENT. LG:ELIM ALL IGNITE SOURCES. NO PERSONS W/OUT WEARING PROTECTIVE EQUIP. STOP AT SOURCE. DIKE AREA TO PREVENT SPREAD, PUMP LIQ TO SALVAGE TANK. TAKE UP REST W/SAND, CLAY, ETC. SHOVEL INTO CONTAINERS. \*

Neutralizing Agent: N/K \*

Waste Disposal Method: DISPOSE OF IN ACCORDANCE WITH ALL LOCAL, STATE AND FEDERAL REGULATIONS. PREVENT RUN-OFF TO SEWERS, STREAMS OR OTHER BODIES OF WATER. IF RUN-OFF OCCURS, NOTIFY PROPER AUTHORITIES AS REQUIRED, THAT A SPILL HAS OCCURRED. \*

Precautions-Handling/Storing: CONTAINERS MAY BE HAZARDOUS WHEN EMPTIED. SINCE EMPTIES RETAIN PRODUCT RESIDUES(VAPOR, LIQUID, SOLID) ALL HAZARD PRECAUTIONS GIVEN MUST BE OBSERVED. \*

Other Precautions: N/K \*

#### ===== Control Measures =====

Respiratory Protection: NIOSH/MSHA APPROVED AIR SUPPLIED RESPIRATOR IS ADVISED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL. OSHA REGS ALSO PERMIT OTHER NIOSH/MSHA RESPIRATORS (NEGATIVE PRESSURE TYPE) UNDER SPECIFIED CONDITIONS. SEE YOUR SAFETY EQUIPMENT SUPPLIER. \*

Report for NIIN: 001818079

Ventilation: PROVIDE SUFFICIENT MECHANICAL (GENERAL &/OR LOCAL EXHAUST)  
VENTILATION \*

Protective Gloves: WEAR RESISTANT GLOVES: POLYETHYLENE \*

Eye Protection: CHEM SPLASH GOGGLES OR SAFETY GLASSES \*

Other Protective Equipment: TO PREVENT REPEATED OR PROLONGED SKIN CONTACT,  
WEAR IMPERVIOUS CLOTHING & BOOTS \*

Work Hygienic Practices: REMOVE CONTAMINATED CLOTHING. LAUNDER  
CONTAMINATED CLOTHING BEFORE RE-USE. \*

Suppl. Safety & Health Data: N/K \*

## **DEFT PRIMER PART A**

**Product Code = 44-W-7 Base**

**Product Description = MIL-P-53030  
Epoxy Polyamid Water  
Reducable Primer**

In order to dispose of this material properly according to state and federal regulations, the following information is submitted.

<b>Raw Material Used</b>	<b>Percent of Formula by Weight</b>
1. Resin (Solids)	16.03
2. Additives (Solids)	0.10
3. Pigments	
a) Titanium Dioxide	33.96
b) Extenders	27.85
4. Solvents	
a) Butanol	10.80
b) Aeromatic hydrocarbon	11.26
<b>Total</b>	<b>100.0</b>

## **DEFT PRIMER PART B**

**Product Code = 44-W-7 Catalyst**

**Product Description = MIL-P-53030  
Epoxy Polyamid  
Catalyst Component**

**In order to dispose of this material properly according to state and federal regulations, the following information is submitted.**

<b>Raw Material Used</b>	<b>Percent of Formula by Weight</b>
1. Resin (Solids)	71.17
2. Additives (Solids)	0.06
3. Solvents	
a) Nitroethane	24.64
b) Aromatic hydrocarbon	4.13
Total	100.0

DOD Hazardous Materials Information System  
DoD 6050.5-L  
AS OF April 1995

FSC: 8010

NIIN: 001605788

Manufacturer's CAGE: 5W216

Part No. Indicator: C

Part Number/Trade Name: THINNER DOPE & LACQUER CELLULOSE NITRATE

===== General Information =====

Item Name: THINNER, DOPE & LACQUER, CELLULOSE NITRATE

Manufacturer's Name: CHEMICAL SPECIALISTS & DEVELOPMENT

Manufacturer's Street: #5 HACKBERRY LANE

Manufacturer's P. O. Box: N/K

Manufacturer's City: CUT & SHOOT

Manufacturer's State: TX

Manufacturer's Country: US

Manufacturer's Zip Code: 77303

Manufacturer's Emerg Ph #: 800-424-9300

Manufacturer's Info Ph #: 409-756-1065

Distributor/Vendor # 1:

Distributor/Vendor # 1 Cage:

Distributor/Vendor # 2:

Distributor/Vendor # 2 Cage:

Distributor/Vendor # 3:

Distributor/Vendor # 3 Cage:

Distributor/Vendor # 4:

Distributor/Vendor # 4 Cage:

Safety Data Action Code:

Safety Focal Point: G

Record No. For Safety Entry: 008

Tot Safety Entries This Stk#: 017

Status: FE

Date MSDS Prepared: 01SEP90

Safety Data Review Date: 12MAR91

Supply Item Manager: GSA

MSDS Preparer's Name: DAVID SHIPP

Preparer's Company: CHEMICAL SPECIALISTS & DEVELOPMENT

Preparer's St Or P. O. Box: #5 HACKBERRY LANE

Preparer's City: CUT & SHOOT

Preparer's State: TX

Preparer's Zip Code: 77303

Other MSDS Number:

MSDS Serial Number: BJZRZ

Specification Number: A-A-857B

Spec Type, Grade, Class: N/K

Hazard Characteristic Code: N/

Unit Of Issue: CN

Unit Of Issue Container Qty: 5 GAL CAN

Type Of Container: METAL

Net Unit Weight: N/K

Used by Ft. Eustis

Report for NIIN: 001605788

NRC/State License Number: N/K  
Net Explosive Weight: N/K  
Net Propellant Weight-Ammo: N/K  
Coast Guard Ammunition Code: N/K

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=====  
**Ingredients/Identity Information**  
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Proprietary: NO  
Ingredient: ISOPROPYL ALCOHOL (SARA III)  
Ingredient Sequence Number: 01  
Percent: 18  
Ingredient Action Code:  
Ingredient Focal Point: G  
NIOSH (RTECS) Number: NT8050000  
CAS Number: 67-63-0  
OSHA PEL: 400 PPM/500 STEL  
ACGIH TLV: 400 PPM/500STEL; 9192  
Other Recommended Limit: NONE SPECIFIED

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Proprietary: NO  
Ingredient: ISOBUTYL ACETATE (SARA III)  
Ingredient Sequence Number: 02  
Percent: 31  
Ingredient Action Code:  
Ingredient Focal Point: G  
NIOSH (RTECS) Number: AI4025000  
CAS Number: 110-19-0  
OSHA PEL: 150 PPM  
ACGIH TLV: 150 PPM; 9192  
Other Recommended Limit: NONE SPECIFIED

-----  
Proprietary: NO  
Ingredient: ALIPHATIC PETROLEUM DISTILLATES (NIOSH 350 MG/CUM-8 HOUR TIME WEIGHT AVERAGE, 1800 MG/CUM BY 15 MINUTES SAMPLE)  
Ingredient Sequence Number: 03  
Percent: 16  
Ingredient Action Code:  
Ingredient Focal Point: G  
NIOSH (RTECS) Number: DE3030000  
CAS Number: 64742-89-8  
OSHA PEL: 300 PPM  
ACGIH TLV: 300 PPM  
Other Recommended Limit: NONE SPECIFIED

-----  
Proprietary: NO  
Ingredient: METHYL ETHYL KETONE (2-BUTANONE) (MEK) (SARA III)  
Ingredient Sequence Number: 04  
Percent: 12  
Ingredient Action Code:  
Ingredient Focal Point: G  
NIOSH (RTECS) Number: EL6475000  
CAS Number: 78-93-3  
OSHA PEL: 200 PPM/300 STEL

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ACGIH TLV: 200 PPM/300 STEL 9192

Other Recommended Limit: NONE SPECIFIED

Proprietary: NO

Ingredient: TOLUENE (SARA III)

Ingredient Sequence Number: 05

Percent: 12

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: XS5250000

CAS Number: 108-88-3

OSHA PEL: 200 PPM/150 STEL

ACGIH TLV: 50 PPM; 9293

Other Recommended Limit: NONE SPECIFIED

Proprietary: NO

Ingredient: N-BUTYL ALCOHOL (SARA III)

Ingredient Sequence Number: 06

Percent: 11

Ingredient Action Code:

Ingredient Focal Point: G

NIOSH (RTECS) Number: EO1400000

CAS Number: 71-36-3

OSHA PEL: 100 PPM

ACGIH TLV: S, C 50 PPM; 9293

Other Recommended Limit: NONE SPECIFIED

#### Physical/Chemical Characteristics

Appearance And Odor: CLEAR, LITTLE IF ANY COLOR; CHARACTERISTIC ODOR

Boiling Point: 175F, 79C

Melting Point: -20F, -29C

Vapor Pressure (MM Hg/70 F): 70 MMHG

Vapor Density (Air=1): 3.0

Specific Gravity: 0.824

Decomposition Temperature: N/K

Evaporation Rate And Ref: SLOWER THAN ETHER

Solubility In Water: MODERATE

Percent Volatiles By Volume: 100

Viscosity: N/K

pH: N/K

Radioactivity: N/K

Form (Radioactive Matl): N/K

Magnetism (Milligauss): N/K

Corrosion Rate (IPY): NONE

Autoignition Temperature: N/K

#### Fire and Explosion Hazard Data

Flash Point: 10 F/-12.2 C

Flash Point Method: N/K

Lower Explosive Limit: 1.2

Upper Explosive Limit: N/K

Extinguishing Media: REGULAR FOAM OR CARBON DIOXIDE OR DRY CHEMICAL  
Special Fire Fighting Proc: WEAR SELF CONTAINED BREATHING APPARATUS W/  
FULL FACEPIECE OPERATED IN POSITIVE PRESS DEMAND MODE. VAPOR MAY TRAVEL TO  
IGNITE SOURCES DISTANT FROM HANDLING POINT

Unusual Fire And Expl Hazrds: NEVER WELD, USE CUTTING TORCH ON OR NEAR  
DRUM(EVEN EMPTY) CAN IGNITE EXPLOSIVELY. ALL 5 GAL PAIL & LARGE METAL  
CONTAINERS GROUND/BOND WHEN TRANSFERRING MATERIAL

=====  
Reactivity Data  
=====

Stability: YES

Cond To Avoid (Stability): N/K

Materials To Avoid: AVOID CONTACT WITH STRONG OXIDIZING AGENTS.

Hazardous Decomp Products: MAY FORM TOXIC MATERIALS. CARBON DIOXIDE &  
CARBON MONOXIDE, VARIOUS HYDROCARBONS, ETC.

Hazardous Poly Occur: NO

Conditions To Avoid (Poly): N/K

=====  
Health Hazard Data  
=====

LD50-LC50 Mixture: N/K

Route Of Entry - Inhalation: YES

Route Of Entry - Skin: YES

Route Of Entry - Ingestion: NO

Health Haz Acute And Chronic: OVEREXPOSURE LIVER ABNORMALITIES &/OR EYE  
DAMAGE. ASPIRATION OF MATERIAL INTO THE LUNGS DUE TO VOMITING CAN CAUSE  
CHEMICAL PNEUMONITIS WHICH CAN BE FATAL.

Carcinogenicity - NTP: N/K

Carcinogenicity - IARC: N/K

Carcinogenicity - OSHA: N/K

Explanation Carcinogenicity: N/K

Signs/Symptoms Of Overexp: EYES:IRRIT, REDNESS, TEARING. SKIN:  
PROLONGED/REPEATED CONTACT CAN CAUSE MODERATE IRRIT, DEFATT, DERMATITIS.  
EXCESSIVE INHALE:NASAL & RESPIRATORY IRRIT, CENTRAL NERVOUS SYSTEM,  
DIZZINESS, WEAKNESS, FATIGUE, NAUSEA, HEADACHE & POSSIBLE UNCONSCIOUSNESS &  
EVEN DEATH. SWALLOW:GASTROINTESTINAL IRRIT, NAUSEA, VOMIT & DIARRHEA

Med Cond Aggravated By Exp: N/K

Emergency/First Aid Proc: SKIN:THOROUGHLY WASH AREA W/SOAP & WATER. REMOVE  
CONTAM CLOTHES. LAUNDER CONTAM CLOTHES BEFORE REUSE. EYES:FLUSH WITH LARGE  
AMOUNTS OF WATER, LIFTING UPPER & LOWER LIDS, GET MED ATTN. SWALLOWED:DO  
NOT INDUCE VOMITING, KEEP PERSON WARM, QUIET & GET MEDICAL ATTENTION.  
BREATH:REMOVE PERSON TO FRESH AIR. IF BREATH IS DIFF ADMIN OXYGEN. BREATH  
HAS STOPPED GIVE CPR. KEEP PERSON WARM, QUIET, GET MED ATTN

=====  
Precautions for Safe Handling and Use  
=====

Steps If Matl Released/Spill: SM:ABSORB LIQ ON PAPER, VERMICULITE, FLOOR  
ABSORBENT. LG:ELIM ALL IGNITE SOURCES. NO PERSONS W/OUT WEARING PROTECTIVE  
EQUIP. STOP AT SOURCE. DIKE AREA TO PREVENT SPREAD, PUMP LIQ TO SALVAGE  
TANK. TAKE UP REST W/SAND, CLAY, ETC. SHOVEL INTO CONTAINERS.\*

Neutralizing Agent: N/K

Waste Disposal Method: DISPOSE OF IN ACCORDANCE WITH ALL LOCAL, STATE AND  
FEDERAL REGULATIONS. \* PREVENT RUN-OFF TO SEWERS, STREAMS OR OTHER BODIES

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OF WATER. IF RUN-OFF OCCURS, NOTIFY PROPER AUTHORITIES AS REQUIRED, THAT A SPILL HAS OCCURRED.

Precautions-Handling/Storing: CONTAINERS MAY BE HAZARDOUS WHEN EMPTIED. SINCE EMPTIES RETAIN PRODUCT RESIDUES (VAPOR, LIQUID, SOLID) ALL HAZARD PRECAUTIONS GIVEN MUST BE OBSERVED.

Other Precautions: N/K

===== Control Measures =====

Respiratory Protection: NIOSH/MSHA APPROVED AIR SUPPLIED RESPIRATOR IS ADVISED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL. OSHA REGS ALSO PERMIT OTHER NIOSH/MSHA RESPIRATORS (NEGATIVE PRESSURE TYPE) UNDER SPECIFIED CONDITIONS. SEE YOUR SAFETY EQUIPMENT SUPPLIER.

Ventilation: PROVIDE SUFFICIENT MECHANICAL (GENERAL &/OR LOCAL EXHAUST) VENTILATION

Protective Gloves: NITRILE RUBBER, POLYETHYLENE

Eye Protection: CHEM SPLASH GOGGLES OR SAFETY GLASSES

Other Protective Equipment: TO PREVENT REPEATED OR PROLONGED SKIN CONTACT, WEAR IMPERVIOUS CLOTHING & BOOTS

Work Hygienic Practices: REMOVE CONTAMINATED CLOTHING. LAUNDER CONTAMINATED CLOTHING BEFORE RE-USE.

Suppl. Safety & Health Data: N/K

## Baseline CARC System Life Cycle Inventory Summary Results

### Table C-1

Notes: █ = User Input

Inventory numbers for individual CARC System components do not include emissions and energy or materials consumption for electric power generation. The "Baseline CARC System" numbers do include electric power generation data.

LCI Components	Units	Thinned TC Quantity	Top Coat Quantity	Thinner Quantity	Primer Quantity	Prim. Pt. A Quantity	Prim. Pt. B Quantity	Baseline CARC System Units	Baseline CARC System Quantity
Usage Rate	ft^2/gal.	200	200	1	1	1	1	BTU/FU	832681.5
Volumetric Mixing Ratio	CARC:thin.							BTU/FU	14348909
Volumetric Mixing Ratio	Pt. A:Pt. B							BTU/FU	588191.3
Specific Gravity								Ib/FU	43695.19
Unit Weight	lb/gal.	0.05145	0.01152	0.0529	7.089	14.59333	9.40752	Ib/FU	2752.657
Usage Rate	lb/ft^2					0.029187	0.004704	ft^2	1000
Functional Unit (FU)									
<b>Resource and Energy Consumption</b>									
Electricity	BTU/lb	10813.64	5881.702	115627	5176.439	12217.84		BTU/FU	
Natural gas	BTU/lb	177054.9	115627	83911.35	293983.5			BTU/FU	
Steam	BTU/lb	6454.894	3576.371	2511.59	2840.313			BTU/FU	
Water	Ib/lb	486.9277	329.4671	352.796	967.3135			Ib/FU	
Crude oil	Ib/lb	33.01711	27.95911	17.41074	47.54899			Ib/FU	
Oxygen	Ib/lb	0.078344	0.156721	0.279948	0.304434			Ib/FU	
Refinery gases	Ib/lb	1.234477	0.293007	0.161095	0.161095			Ib/FU	
Cobalt oxide	Ib/lb		0.0195					Ib/FU	71.59119
Chrome oxide	Ib/lb		0.0885					Ib/FU	1.003275
Silica	Ib/lb		0.26					Ib/FU	4.553325
Iron ore	Ib/lb		0.023108					Ib/FU	13.6572
Magnetite	Ib/lb		0.007703					Ib/FU	1.281821
Magnesium ore	Ib/lb		0.043719					Ib/FU	0.396294
Sodium Chloride	Ib/lb		0.504494					Ib/FU	2.249343
Phosphoric acid	Ib/lb		0.000926					Ib/FU	43.08366
Sulfuric acid	Ib/lb		0.052292					Ib/FU	0.047642
Sulfur dioxide	Ib/lb		0.000044					Ib/FU	6.041725
Hydrocarbons C8 to C10	Ib/lb		0.00033	0		0		Ib/FU	0.002242
Proprietary Primer Ingredients	Ib/lb							Ib/FU	0.016979
Chlorine	Ib/lb							Ib/FU	0
Coal	Ib/lb							Ib/FU	13.20812
Phosphate ore	Ib/lb							Ib/FU	0.291794
								Ib/FU	2.092124



C-3

Dichlorodifluoromethane	0	Ib/FU	0
Methanol	0	Ib/FU	0
Naphthalene	0	Ib/FU	0
Nitric acid	0	Ib/FU	0
Butyl alcohol	0	Ib/FU	0
Nitroethane	0	Ib/FU	0.03424
Aliphatic hydrocarbons	0	Ib/FU	0
			0
<b>Wastewater Emissions</b>			
Wastewater	34.85286	34.39827	24.87046
WW Reinf'd	1.939361	1.642264	89.14841
WW Discharg.	0.857607	0.726227	1.022673
WW Injected	0.281159	0.238087	2.792936
Arsenic	3.5E-07	3.0E-07	0.452237
Benzene	8.6E-06	7.2E-06	1.235067
Boron	0.000182	0.000154	0.148262
Sodium	0.172821	0.146346	0.404906
Chloride	0.136437	0.115536	1.9E-07
Mobile ions	0.418408	0.354311	5.1E-07
Oil and Grease	0.00426	0.003607	4.5E-06
Cadmium	2.9E-06	2.5E-06	0.000164
Chromium	2.6E-07	2.2E-07	4.2E-06
Mercury	6.6E-08	5.6E-08	0.000018
Thallium	6.3E-08	5.3E-08	3.8E-07
Sulfuric Acid			0.071947
Iron			0.196488
Dissolved Solids			0.220637
Suspended Solids			0.602563
COD			0.602563
Phenol			0.220637
Sulfide			0.602563
Oil			0.602563
Acid			0.602563
Metals			0.602563
BOD			0.602563
Vanadium			0.602563
Zinc			0.602563
Copper			0.602563
Aluminum			0.602563
Titanium dioxide			0.602563
Lead			0.602563
			0.000061

Magnesium	4.1E-09	0.0008326	Ib/FU	1.2E-07
Chlorine		0.0008326	Ib/FU	0.039165
Ammonia		0	Ib/FU	0
Hydrogen cyanide		0	Ib/FU	0
<b>Solid Wastes</b>	<b>Ib/Ib</b>			
<b>Solid Wastes</b>	<b>Ib/Ib</b>			
<b>Hazardous Wastes</b>				
Fly Ash	0.27641	0.000753	Ib/FU	62.14026
Bottom Ash	0.000132	0.07913	Ib/FU	80.80762
Slag			Ib/FU	2.0E-09
FGD Solids			Ib/FU	5.7E-10
U238			Ib/FU	2.2E-10
U236			Ib/FU	7.9E-10
U235			Ib/FU	5.4E-09
Pu (fissile)			Ib/FU	3.6E-12
Pu (nonfissile)			Ib/FU	4.5E-11
<b>Fission Products</b>		0	Ib/FU	3.7E-11
2-nitropropane			Ib/FU	1.4E-11
Acetaldehyde			Ib/FU	2.6E-11
Acetone			Ib/FU	0
Acetonitrile			Ib/FU	0
Formaldehyde			Ib/FU	0
Methanol			Ib/FU	0
Naphthalene			Ib/FU	0
Nitric acid			Ib/FU	0
Ammonia			Ib/FU	0
Hydrogen cyanide		0	Ib/FU	0

Table C-2  
Alternative Primer CARC System Life Cycle Inventory Summary Results

Notes: █ = User Input

Inventory numbers for individual CARC System components do not include emissions and energy or materials consumption for electric power generation. The "Baseline CARC System" numbers do include electric power generation data.

LCI Components	Usage Rate	Units	Thinned TC Top Coat		Primer Quantity	Prim. Pt. A Quantity	Prim. Pt. B Quantity	Baseline CARC System Units	Baseline CARC System Quantity
			Quantity	Quantity					
Volumetric Mixing Ratio	█	█	█	█	█	█	█	█	█
Volumetric Mixing Ratio	CARC:thin. Pt. A:Pt. B	█	█	█	█	█	█	█	█
Specific Gravity	█	█	█	█	█	█	█	█	█
Unit Weight	lb/gal.	lb/ft <sup>2</sup>	█	█	█	█	█	█	█
Usage Rate	█	█	█	█	█	█	█	█	█
Functional Unit (FU)	█	█	0.05145	0.01152	7.089	0.028514	0.004706	0.004706	█
<b>Resource and Energy Consumption</b>									
Electricity	BTU/lb	BTU/lb	10813.64	5881.702	2849.335	12388.93	763573.7	BTU/FU	BTU/FU
Natural gas	BTU/lb	BTU/lb	177054.9	115627	44822.11	199001.2	12731376	BTU/FU	BTU/FU
Steam	BTU/lb	BTU/lb	6454.894	3576.371	696.0441	3090.297	535913.5	BTU/FU	BTU/FU
Water	lb/lb	lb/lb	486.8277	329.4671	248.7911	907.1772	40210.77	lb/FU	lb/FU
Crude oil	lb/lb	lb/lb	33.01711	27.95911	8.404271	37.31328	2436.041	lb/FU	lb/FU
Oxygen	lb/lb	lb/lb	0.078344	0.158721	0.214204	0.288878	13.19986	lb/FU	lb/FU
Refinery gases	lb/lb	lb/lb	1.234477	0.293007	0	0	66.88931	lb/FU	lb/FU
Cobalt oxide	lb/lb	lb/lb	0.0195	0.0885	0.0885	0	1.003275	lb/FU	lb/FU
Chrome oxide	lb/lb	lb/lb	0.0885	0.26	0.26	0	4.553325	lb/FU	lb/FU
Silica	lb/lb	lb/lb	0.023108	0.00534	0.00534	0	13.377	lb/FU	lb/FU
Iron ore	lb/lb	lb/lb	0.007703	0.043719	0.043719	0	1.341152	lb/FU	lb/FU
Magnetite	lb/lb	lb/lb	0.0504494	0.504494	0.504494	0	0.398294	lb/FU	lb/FU
Magnesium ore	lb/lb	lb/lb	0.000926	0.052292	0.052292	0	2.249343	lb/FU	lb/FU
Sodium Chloride	lb/lb	lb/lb	0.052292	0.000044	0.000044	0	43.46918	lb/FU	lb/FU
Phosphoric acid	lb/lb	lb/lb	0.000033	0.00033	0.00033	0	0.047642	lb/FU	lb/FU
Sulfuric acid	lb/lb	lb/lb	0.000044	0.000044	0.000044	0	8.181103	lb/FU	lb/FU
Sulfur dioxide	lb/lb	lb/lb	0	0.002477	0.002477	0.000909	0.002242	lb/FU	lb/FU
Hydrocarbons C8 to C10	lb/lb	lb/lb	0	0	0	0	0.091889	lb/FU	lb/FU
Proprietary Primer Ingredients	lb/lb	lb/lb	0	0.332521	0.332521	1.120572	0	14.75451	lb/FU
Chlorine	lb/lb	lb/lb	0	0	0	0	0.000016	lb/FU	lb/FU
Coal	lb/lb	lb/lb	0	0	0	0	0	14.75451	lb/FU
Phosphate ore	lb/lb	lb/lb	0	0	0	0	0	0	0

Zinc ore	Ib/lb	0
Uranium	Ib/FU	3.8E-09
Distillate Fuel Oil	Ib/FU	3.9E-07
Hydropotential	Ib/FU	4.4E-06
Rumenite	Ib/lb	0.135076
Air	Ib/lb	0.348251
Coke	Ib/lb	4.370365
Sodium hydroxide	Ib/lb	0.061637
Starch	Ib/lb	0.018491
Fuel	Ib/lb	0.003082
Soda ash	Ib/lb	2247.6
Limestone	Ib/lb	
Bauxite	Ib/lb	
<b>Air Emissions</b>		
CO	Ib/lb	0.011186
PM	Ib/lb	0.106336
SOx	Ib/lb	0.008263
VOC	Ib/lb	0.234812
Benzene	Ib/lb	0.001902
Toluene	Ib/lb	0.000249
Ethylbenzene	Ib/lb	0.000025
Xylene	Ib/lb	0.000184
Cumene	Ib/lb	0.000242
Phenol	Ib/lb	0.000242
Heavy Aromatics	Ib/lb	0.003635
NOx	Ib/lb	0.103415
PM10	Ib/lb	0.020305
Acetaldehyde	Ib/lb	0.000076
Ethylene	Ib/lb	3.6E-06
HCN	Ib/lb	0.000131
Chlorine	Ib/lb	0.005808
MEK	Ib/lb	0
Isobutyraldehyde	Ib/lb	0.028462
Acetone	Ib/lb	0.0001
Ammonia	Ib/lb	0.000025
Fluorine	Ib/lb	0
Lead	Ib/lb	0

#### Air Emissions

Zinc ore	Ib/FU	0
Uranium	Ib/FU	3.8E-09
Distillate Fuel Oil	Ib/FU	3.9E-07
Hydropotential	Ib/FU	4.4E-06
Rumenite	Ib/FU	0.135076
Air	Ib/FU	0.348251
Coke	Ib/FU	4.370365
Sodium hydroxide	Ib/FU	0.061637
Starch	Ib/FU	0.018491
Fuel	Ib/FU	0.003082
Soda ash	Ib/FU	2247.6
Limestone	Ib/FU	
Bauxite	Ib/FU	
<b>Air Emissions</b>		
CO	Ib/FU	0.002361
PM	Ib/FU	0.000465
SOx	Ib/FU	0.001298
VOC	Ib/FU	0.047286
Benzene	Ib/FU	0.113862
Toluene	Ib/FU	0.01981
Ethylbenzene	Ib/FU	0.083488
Xylene	Ib/FU	0.000077
Cumene	Ib/FU	0.000342
Phenol	Ib/FU	0.000029
Heavy Aromatics	Ib/FU	0.000126
NOx	Ib/FU	0.000094
PM10	Ib/FU	0.000076
Acetaldehyde	Ib/FU	0.000132
Ethylene	Ib/FU	0.000459
HCN	Ib/FU	0.000204
Chlorine	Ib/FU	0.000138
MEK	Ib/FU	0.000904
Isobutyraldehyde	Ib/FU	0.020629
Acetone	Ib/FU	0.197299
Ammonia	Ib/FU	5.877492
Fluorine	Ib/FU	0.020379
Lead	Ib/FU	0.327885



<b>Dichlorodifluoromethane</b>	Ib/FU	0.000234
<b>Methanol</b>	Ib/FU	4.0E-06
<b>Naphthalene</b>	Ib/FU	0.000137
<b>Nitric acid</b>	Ib/FU	5.5E-06
<b>Butyl alcohol</b>	Ib/FU	0.041712
<b>Nitroethane</b>	Ib/FU	0.0003868
<b>Aliphatic hydrocarbons</b>	Ib/FU	0
<b>Wastewater Emissions</b>		
<b>Wastewater</b>	Ib/lb	34.85288
<b>WW Reinf'd</b>	Ib/lb	1.939361
<b>WW Discharg.</b>	Ib/lb	0.857607
<b>WW Injected</b>	Ib/lb	0.281159
<b>Arsenic</b>	Ib/lb	3.5E-07
<b>Benzene</b>	Ib/lb	8.6E-06
<b>Boron</b>	Ib/lb	0.000182
<b>Sodium</b>	Ib/lb	0.172821
<b>Chloride</b>	Ib/lb	0.136437
<b>Mobile Ions</b>	Ib/lb	0.418408
<b>Oil and Grease</b>	Ib/lb	0.00428
<b>Cadmium</b>	Ib/lb	2.9E-06
<b>Chromium</b>	Ib/lb	2.6E-07
<b>Mercury</b>	Ib/lb	6.6E-08
<b>Thallium</b>	Ib/lb	6.3E-08
<b>Sulfuric Acid</b>		
<b>Iron</b>	Ib/FU	0.000441
<b>Dissolved Solids</b>		
<b>Suspended Solids</b>	Ib/FU	6.3E-07
<b>COD</b>	Ib/FU	2.1E-09
<b>Phenol</b>	Ib/FU	4.1E-09
<b>Sulfide</b>	Ib/FU	3.5E-10
<b>Oil</b>	Ib/FU	3.5E-10
<b>Acid</b>	Ib/FU	1.3E-09
<b>Metals</b>	Ib/FU	7.5E-08
<b>BOD</b>	Ib/FU	2.4E-08
<b>Vanadium</b>	Ib/FU	0.000213
<b>Zinc</b>	Ib/FU	0.000068
<b>Copper</b>	Ib/FU	0.000968
<b>Aluminum</b>	Ib/FU	0.213034
<b>Titanium dioxide</b>	Ib/FU	0.0002905
<b>Lead</b>	Ib/FU	0.000102

Magnesium	1.9E-07	Ib/FU	
Chlorine	0.1212	Ib/FU	
Ammonia	1.7E-06	Ib/FU	
Hydrogen cyanide	1.2E-07	Ib/FU	
<b>Solid Wastes</b>			
<b>Solid Wastes</b>	<b>0.27641</b>	<b>Ib/lb</b>	<b>0.025758</b>
<b>Hazardous Wastes</b>	<b>0.000132</b>	<b>Ib/lb</b>	<b>3.7E-07</b>
Fly Ash			
Bottom Ash			
Slag			
FGD Solids			
U238			
U236			
U235			
Pu (fissile)			
Pu (nonfissile)			
<b>Fission Products</b>			
2-nitropropane			
Acetaldehyde			
Acetone			
Acetonitrile			
Formaldehyde			
Methanol			
Naphthalene			
Nitric acid			
Ammonia			
Hydrogen cyanide			

### Alternative Gun CARC System Life Cycle Inventory Summary Results

Notes: [REDACTED] = User Input

**Table C-3**

**Inventory numbers for individual CARC System components do not include emissions and energy or materials consumption for electric power generation. The "Baseline CARC System" numbers do include electric power generation data.**

LCI Components	Units	Thinned TC		Primer		Prim. Pt. A		Prim. Pt. B		Baseline CARC System Units	Baseline CARC System Quantity
		Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity		
Usage Rate	ft^2/gal.	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	BTU/FU	605433
Volumetric Mixing Ratio	CARC:thin.	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	BTU/FU	10464120
Volumetric Mixing Ratio	Pt. A:Pt. B	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	BTU/FU	462898.2
Specific Gravity		[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	31785.09
Unit Weight	lb/gal.	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	2007.554
Usage Rate	lb/ft^2	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	11.25989
Functional Unit (FU)		0.037147	0.009038	7.089	14.59333	9.40752	0.021073	0.003398	Ib^2	Ib/FU	51.90009
<b>Resource and Energy Consumption</b>											
Electricity	BTU/lb	10813.84	5881.702	5176.439	12217.84					BTU/FU	
Natural gas	BTU/lb	177054.9	115827	83911.35	293983.5					BTU/FU	
Steam	BTU/lb	8454.894	3576.371	2511.59	2840.313					BTU/FU	
Water	lb/lb	486.9277	329.4671	352.798	987.3135					Ib/FU	
Crude oil	lb/lb	33.01711	27.95911	17.41074	47.54899					Ib/FU	
Oxygen	lb/lb	0.078344	0.158721	0.278948	0.304434					Ib/FU	
Refinery gases	lb/lb	1.234477	0.293007	0.161095						Ib/FU	
Cobalt oxide	lb/lb	0.0195								Ib/FU	
Chrome oxide	lb/lb	0.0885								Ib/FU	
Silica	lb/lb	0.28								Ib/FU	
Iron ore	lb/lb	0.023108								Ib/FU	
Magnetite	lb/lb	0.007703								Ib/FU	
Magnesium ore	lb/lb	0.043719								Ib/FU	
Sodium Chloride	lb/lb	0.504494								Ib/FU	
Phosphoric acid	lb/lb	0.000926								Ib/FU	
Sulfuric acid	lb/lb	0.052292								Ib/FU	
Sulfur dioxide	lb/lb	0.000044								Ib/FU	
Hydrocarbons C8 to C10	lb/lb	0.00033	0	0	0	0	0	0		Ib/FU	
Proprietary Primer Ingredients	lb/lb									Ib/FU	
Chlorine	lb/lb									Ib/FU	
Coal	lb/lb									Ib/FU	
Phosphate ore	lb/lb									Ib/FU	



MIBK	0.014318	Ib/FU	0
Isopropyl alcohol	0	Ib/FU	0
MIAK	0.007743	Ib/FU	0.287645
Aromatic hydrocarbons	0.000316	Ib/FU	0.01203
Butyl acetate	0.000319	Ib/FU	0.079413
Naphtha	0.0001032	Ib/FU	0.034357
Propyl acetate	0	Ib/FU	0
MPK	0	Ib/FU	0
Butyl cellosolve	0	Ib/FU	0
Hexyl acetate	0	Ib/FU	0
CO2	3.523738	Ib/FU	0.034673
Hexane	0.000798	Ib/FU	218.9921
Heptane	0.001028	Ib/FU	0.048549
Octane	0.000887	Ib/FU	0.06251
C-7 cycloparaffins	0.000582	Ib/FU	0.041802
C-8 cycloparaffins	0.000145	Ib/FU	0.008807
Pentane	0.000053	Ib/FU	0.00322
Methane	0.000499	Ib/FU	0.030315
Ethane	0.000331	Ib/FU	0.201348
Propane	0.00057	Ib/FU	0.034629
n-Butane	0.000482	Ib/FU	0.054323
Iso-Butane	0.000893	Ib/FU	0.043037
Formaldehyde	0.000757	Ib/FU	0.002146
Hydrocarbons	0.000251	Ib/FU	0.015276
Aldehydes	0.039831	Ib/FU	2.421871
Organic Acids	0.000232	Ib/FU	0.014093
Kerosene	0.000198	Ib/FU	0.017937
Carbon tetrachloride	0.00025	Ib/FU	3.2E-09
Chloroform	0.000295	Ib/FU	0.000599
Ethyl chloride	0	Ib/FU	0.000284
Ethylene dichloride	0	Ib/FU	0.000637
Trichloroethane	0	Ib/FU	0.001647
Vinyl chloride	0	Ib/FU	0.000487
Hydrochloric acid	0	Ib/FU	0.000303
Sulfuric acid	0	Ib/FU	0.000953
Propylene	0	Ib/FU	0
1,2-butylene	0	Ib/FU	0
2-nitropropane	0	Ib/FU	0
Acetonitrile	0	Ib/FU	0
Bromochlorodifluoromethane	0	Ib/FU	0
Bromotrifluoromethane	0	Ib/FU	0

Dichlorodifluoromethane	Ib/FU	0
Methanol	Ib/FU	0
Naphthalene	Ib/FU	0
Nitric acid	Ib/FU	0
Butyl alcohol	Ib/FU	0
Nitroethane	Ib/FU	0.017849
Aliphatic hydrocarbons	Ib/FU	0
<b>Wastewater Emissions</b>		
Wastewater	Ib/lb	34.85288
WW Reinf'd	Ib/lb	1.939361
WW Discharg.	Ib/lb	1.642264
WW Injected	Ib/lb	0.857607
Arsenic	Ib/lb	0.728227
Benzene	Ib/lb	0.281159
Boron	Ib/lb	3.5E-07
Sodium	Ib/lb	8.6E-08
Chloride	Ib/lb	7.2E-08
Mobile Ions	Ib/lb	0.000154
Oil and Grease	Ib/lb	0.000182
Cadmium	Ib/lb	0.172821
Chromium	Ib/lb	0.146346
Mercury	Ib/lb	0.136437
Thallium	Ib/lb	0.115536
Sulfuric Acid	Ib/lb	0.418408
Iron	Ib/lb	0.354311
Dissolved Solids	Ib/lb	0.00426
Suspended Solids	Ib/lb	0.003607
COD	Ib/lb	2.9E-06
Phenol	Ib/lb	2.6E-07
Sulfide	Ib/lb	6.6E-08
Oil	Ib/lb	6.3E-08
Acid	Ib/lb	5.3E-08
Metals	Ib/lb	5.3E-08
BOD	Ib/lb	9.6E-08
Zinc	Ib/lb	3.3E-08
Copper	Ib/lb	9.0E-08
Aluminum	Ib/lb	3.8E-06
Titanium dioxide	Ib/lb	6.8E-08
Lead	Ib/lb	5.9E-06
		0.000263
<b>C-14</b>		
	Ib/FU	24.87046
	Ib/FU	89.14841
	Ib/FU	1.022673
	Ib/FU	2.792936
	Ib/FU	1.235087
	Ib/FU	0.452237
	Ib/FU	0.148262
	Ib/FU	0.404906
	Ib/FU	1.9E-07
	Ib/FU	5.1E-07
	Ib/FU	4.5E-08
	Ib/FU	0.000012
	Ib/FU	0.000086
	Ib/FU	0.000262
	Ib/FU	0.091133
	Ib/FU	0.248885
	Ib/FU	0.071947
	Ib/FU	0.198488
	Ib/FU	0.220637
	Ib/FU	0.602583
	Ib/FU	0.006134
	Ib/FU	0.002246
	Ib/FU	0.000164
	Ib/FU	4.2E-06
	Ib/FU	0.000018
	Ib/FU	3.8E-07
	Ib/FU	0.00004
	Ib/FU	4.4E-06
	Ib/FU	9.6E-08
	Ib/FU	3.3E-08
	Ib/FU	9.0E-08
	Ib/FU	5.9E-06
	Ib/FU	5.0E-07
	Ib/FU	1.7E-09
	Ib/FU	3.3E-09
	Ib/FU	2.7E-10
	Ib/FU	5.5E-10
	Ib/FU	5.5E-10
	Ib/FU	2.7E-10
	Ib/FU	9.9E-10
	Ib/FU	0.000094
	Ib/FU	0.00003
	Ib/FU	0.00003
	Ib/FU	0.000427
	Ib/FU	0.09388
	Ib/FU	0.00128

<b>Magnesium</b>	<b>4.1E-09</b>	<b>0.008326</b>	<b>lb/FU</b>	<b>8.5E-08</b>
<b>Chlorine</b>			<b>lb/FU</b>	<b>0.028275</b>
<b>Ammonia</b>			<b>lb/FU</b>	<b>0</b>
<b>Hydrogen cyanide</b>			<b>lb/FU</b>	<b>0</b>
 <b>Solid Wastes</b>			 <b>lb/lb</b>	
<b>Solid Wastes</b>	<b>0.27641</b>	<b>0.000753</b>	<b>lb/lb</b>	<b>0.593855</b>
<b>Hazardous Wastes</b>	<b>0.000132</b>	<b>0.000284</b>	<b>lb/lb</b>	<b>0.551663</b>
<b>Fly Ash</b>			<b>lb/FU</b>	<b>52.84637</b>
<b>Bottom Ash</b>			<b>lb/FU</b>	<b>80.16332</b>
<b>Slag</b>			<b>lb/FU</b>	<b>1.5E-09</b>
<b>FGD Solids</b>			<b>lb/FU</b>	<b>4.1E-10</b>
<b>U238</b>			<b>lb/FU</b>	<b>1.6E-10</b>
<b>U236</b>			<b>lb/FU</b>	<b>5.7E-10</b>
<b>U235</b>			<b>lb/FU</b>	<b>3.9E-09</b>
<b>Pu (fissile)</b>			<b>lb/FU</b>	<b>2.6E-12</b>
<b>Pu (nonfissile)</b>			<b>lb/FU</b>	<b>3.3E-11</b>
<b>Fission Products</b>			<b>lb/FU</b>	<b>2.7E-11</b>
<b>2-nitropropane</b>			<b>lb/FU</b>	<b>1.0E-11</b>
<b>Acetaldehyde</b>			<b>lb/FU</b>	<b>1.9E-11</b>
<b>Acetone</b>			<b>lb/FU</b>	<b>0</b>
<b>Acetonitrile</b>			<b>lb/FU</b>	<b>0</b>
<b>Formaldehyde</b>			<b>lb/FU</b>	<b>0</b>
<b>Methanol</b>			<b>lb/FU</b>	<b>0</b>
<b>Naphthalene</b>			<b>lb/FU</b>	<b>0</b>
<b>Nitric acid</b>			<b>lb/FU</b>	<b>0</b>
<b>Ammonia</b>			<b>lb/FU</b>	<b>0</b>
<b>Hydrogen cyanide</b>			<b>lb/FU</b>	<b>0</b>

**Table C-4**  
**Alternative Gun and Primer CARC System Life Cycle Inventory Summary Results**

Notes: [REDACTED] = User Input

Inventory numbers for individual CARC System components do not include emissions and energy or materials consumption for electric power generation. The "Baseline CARC System" numbers do include electric power generation data.

LCI Components	Usage Rate	Baseline CARC System			
		Units	Thinned TC Top Coat Quantity	Primer Quantity	Prim. Pt. A Prim. Pt. B Quantity
Volumetric Mixing Ratio	ft^2/gal.	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
Volumetric Mixing Ratio	CARC/thin.	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
Specific Gravity	Pt. A:Pt. B	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
Unit Weight	lb/gal.	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
Usage Rate	lb/ft^2	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
Functional Unit (FU)		0.037147	0.009038	0.020587	0.003397
<b>Resource and Energy Consumption</b>					
Electricity	BTU/lb	10813.84	5881.702	2849.335	12368.93
Natural gas	BTU/lb	177054.9	115627	44822.11	199001.2
Steam	BTU/lb	6454.894	3576.371	696.0441	3090.297
Water	lb/lb	486.9277	329.4671	248.7911	907.1772
Crude oil	lb/lb	33.01711	27.95911	8.404271	37.31328
Oxygen	lb/lb	0.078344	0.158721	0.214204	0.266876
Refinery gases	lb/lb	1.234477	0.293007	0	0
Cobalt oxide	lb/lb	0.0195	0.0885	0	0
Chrome oxide	lb/lb	0.0885	0.26	0	0
Silica	lb/lb	0.023108	0.023108	0.00534	0.00534
Iron ore	lb/lb	0.007703	0.043719	0.000926	0.000926
Magnetite	lb/lb	0.043719	0.504494	0.052292	0.052292
Magnesium ore	lb/lb	0.000044	0.000044	0.000033	0.000033
Sodium Chloride	lb/lb	0.000033	0	0.002477	0.000809
Phosphoric acid	lb/lb	0	0.35447	1.573775	1.573775
Sulfuric acid	lb/lb	0	0.192562	0.192562	0.192562
Sulfur dioxide	lb/lb	0	0	0	0
Hydrocarbons C8 to C10	lb/lb	0	0	0.332521	1.120572
Proprietary Primer Ingredients	lb/lb	0	0	0	0
Chlorine	lb/lb	0	0	0	0
Coal	lb/lb	0	0	0	0
Phosphate ore	lb/lb	0	0	0	0

Zinc ore	Ib/FU	0	
Uranium	Ib/FU	2.8E-09	
Distillate Fuel Oil	Ib/FU	2.8E-07	
Residual Fuel Oil	Ib/FU	3.2E-06	
Hydropotential	Ib/FU	0.004586	
Ilmenite	Ib/FU	7.16945	
Rumenite	Ib/FU	89.97271	
Air	Ib/FU	1.2668929	
Coke	Ib/FU	0.018491	
Sodium hydroxide	Ib/FU	0.3808779	
SiAl	Ib/FU	0.063446	
Fuel	Ib/FU	46271.34	
Starch	Ib/FU	0.209911	
Soda ash	Ib/FU	2.623886	
Limestone	Ib/FU	4.653024	
Bauxite	Ib/FU	83.96435	
<b>Air Emissions</b>			
CO	Ib/lb	0.002361	0.01016
PM	Ib/lb	0.000465	0.001296
SOx	Ib/lb	0.047286	0.113682
VOC	Ib/lb	0.010748	0.01991
Benzene	Ib/lb	0.234812	0.053488
Toluene	Ib/lb	0.001902	0.000977
Ethylbenzene	Ib/lb	0.000249	0.000342
Xylene	Ib/lb	0.000025	0.000029
Cumene	Ib/lb	9.7E-06	0.000126
Phenol	Ib/lb	0.000164	0.000078
Heavy Aromatics	Ib/lb	9.7E-06	0.001132
NOx	Ib/lb	0.0000242	0.0000459
PM10	Ib/lb	0.0000242	0.0000204
Acetaldehyde	Ib/lb	0.0000242	0.0000904
Ethylene	Ib/lb	0.0000242	0.0000138
HCN	Ib/lb	0.0000242	0.0000804
Chlorine	Ib/lb	0.0000242	0.0000904
MEK	Ib/lb	0.0000242	0.0000904
Isobutylaldehyde	Ib/lb	0.0000242	0.0000904
Acetone	Ib/lb	0.0000242	0.0000904
Ammonia	Ib/lb	0.0000242	0.0000904
Fluorine	Ib/lb	0.0000242	0.0000904
Lead	Ib/lb	0.0000242	0.0000904



Dichlorodifluoromethane	0.000234	Ib/FU	0.000795
Methanol	4.0E-06	Ib/FU	0.000014
Naphthalene	0.000137	Ib/FU	0.000464
Nitric acid	1.2E-06	Ib/FU	4.0E-06
Butyl alcohol	0.0021743	Ib/FU	0.002016
Nitroethane	0	Ib/FU	0
Aliphatic hydrocarbons	0	Ib/FU	0
<b>Wastewater Emissions</b>			
Wastewater	34.85288	34.39827	14.92558
VW Reinf'd	1.939361	1.842264	0.493651
VW Discharg.	0.857607	0.728227	0.218298
VW Injected	0.281159	0.238087	0.071587
Arsenic	3.5E-07	3.0E-07	9.0E-08
Benzene	8.6E-06	7.2E-06	2.2E-06
Boron	0.000182	0.000154	0.000046
Sodium	0.172821	0.146346	0.04398
Chloride	0.136437	0.115536	0.034728
Mobile ions	0.418408	0.354311	0.106503
Oil and Grease	0.00426	0.003607	0.001084
Cadmium	2.9E-06	2.5E-06	0.000272
Chromium	2.6E-07	2.2E-07	0.000031
Mercury	6.6E-06	5.6E-06	4.7E-06
Thallium	6.3E-06	5.3E-06	1.6E-06
Sulfuric Acid			0.000441
Iron			
Dissolved Solids			
Suspended Solids			
COD			
Phenol			
Sulfide			
Oil			
Acid			
Metals			
BOD			
Vanadium			
Zinc			
Copper			
Aluminum			
Titanium dioxide			
Lead			

<b>Magnesium</b>	<b>6.0E-09</b>	<b>0.025758</b>	<b>Ib/FU</b>	<b>1.4E-07</b>
<b>Chlorine</b>			<b>Ib/FU</b>	<b>0.087495</b>
<b>Ammonia</b>			<b>Ib/FU</b>	<b>1.3E-06</b>
<b>Hydrogen cyanide</b>			<b>Ib/FU</b>	<b>8.4E-08</b>
<b>Solid Wastes</b>				
<b>Solid Wastes</b>	<b>lb/lb</b>	<b>0.27641</b>	<b>0.000753</b>	<b>0.442818</b>
<b>Hazardous Wastes</b>	<b>lb/lb</b>	<b>0.000132</b>	<b>0.03398</b>	<b>1.513695</b>
<b>Fly Ash</b>				<b>0</b>
<b>Bottom Ash</b>				
<b>Slag</b>				
<b>FGD Solids</b>				
<b>U238</b>				
<b>U236</b>				
<b>U235</b>				
<b>Pu (fissile)</b>				
<b>Pu (nonfissile)</b>				
<b>Fission Products</b>				
<b>2-nitropropane</b>				<b>0.001717</b>
<b>Acetaldehyde</b>				<b>0.002214</b>
<b>Acetone</b>				<b>0.001188</b>
<b>Acetonitrile</b>				<b>0.000989</b>
<b>Formaldehyde</b>				<b>0.000017</b>
<b>Methanol</b>				<b>0.001951</b>
<b>Naphthalene</b>				<b>0.006628</b>
<b>Nitric acid</b>				<b>1.4E-06</b>
<b>Ammonia</b>				<b>4.8E-06</b>
<b>Hydrogen cyanide</b>				<b>0.000137</b>
				<b>0.00003</b>
				<b>1.4E-06</b>
				<b>4.8E-06</b>

**Alternative Thinner CARC System Life Cycle Inventory Summary Results**

Notes: [REDACTED] = User Input

Inventory numbers for individual CARC System components do not include emissions and energy or materials consumption for electric power generation. The "Baseline CARC System" numbers do include electric power generation data.

LCI Components	Units	Thinned TC Top Coat Quantity	Thinner Quantity	Primer Quantity	Prim. Pt. A Quantity	Prim. Pt. B Quantity	Baseline CARC System Units	Baseline CARC System Quantity
Usage Rate	ft <sup>2</sup> /gal.	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	BTU/FU	768298.9
Volumetric Mixing Ratio	CARC:thin.	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	BTU/FU	13071060
Volumetric Mixing Ratio	Pl. A:Pl. B	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	BTU/FU	547298.8
Specific Gravity		[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	40071.31
Unit Weight	lb/gal.	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	2449.64
Usage Rate	lb/ft <sup>2</sup>	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	13.74273
Functional Unit (FU)		0.05145	0.001117	[REDACTED]	14.59333	9.40752	ft <sup>2</sup>	[REDACTED]
<b>Resource and Energy Consumption</b>								
Electricity	BTU/lb	10813.84	3020.153	5178.439	12217.84	[REDACTED]	BTU/FU	768298.9
Natural gas	BTU/lb	177054.9	48511.73	83911.35	293903.5	[REDACTED]	BTU/FU	13071060
Steam	BTU/lb	8454.894	275.1848	2511.59	2840.313	[REDACTED]	BTU/FU	547298.8
Water	Ib/lb	486.9277	153.6514	352.798	987.3135	[REDACTED]	Ib/FU	40071.31
Crude oil	Ib/lb	33.01711	17.0792	17.41074	47.54689	[REDACTED]	Ib/FU	2449.64
Oxygen	Ib/lb	0.078344	0.067828	0.279948	0.304434	[REDACTED]	Ib/FU	13.74273
Refinery gases	Ib/lb	1.234477	0.192075	0.161095	[REDACTED]	[REDACTED]	Ib/FU	68.43024
Cobalt oxide	Ib/lb	0.0195	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	1.003275
Chrome oxide	Ib/lb	0.0885	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	4.553325
Silica	Ib/lb	0.26	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	13.6572
Iron ore	Ib/lb	0.023108	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	1.281821
Magnetite	Ib/lb	0.007703	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	0.396294
Magnesium ore	Ib/lb	0.043719	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	2.249343
Sodium Chloride	Ib/lb	0.504494	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	43.08366
Phosphoric acid	Ib/lb	0.000926	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	0.047642
Sulfuric acid	Ib/lb	0.052292	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	6.041725
Sulfur dioxide	Ib/lb	0.000044	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	0.002242
Hydrocarbons C8 to C10	Ib/lb	0.00033	0	0	0	0	Ib/FU	0.016979
Proprietary Primer Ingredients	Ib/lb	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	Ib/FU	0
Chlorine	Ib/lb	[REDACTED]	[REDACTED]	[REDACTED]	0.39417	0.362135	Ib/FU	13.20812
Coal	Ib/lb	[REDACTED]	[REDACTED]	[REDACTED]	0.009997	[REDACTED]	Ib/FU	0.291793
Phosphate ore	Ib/lb	[REDACTED]	[REDACTED]	[REDACTED]	0.07168	[REDACTED]	Ib/FU	2.092124

<b>0.286</b>	<b>Zinc ore</b>	<b>Ib/FU</b>	<b>3.8E-09</b>
	<b>Uranium</b>	<b>Ib/FU</b>	<b>3.9E-07</b>
	<b>Distillate Fuel Oil</b>	<b>Ib/FU</b>	<b>4.5E-06</b>
	<b>Residual Fuel Oil</b>	<b>Ib/FU</b>	<b>0.006343</b>
	<b>Hydropotential</b>	<b>m^3-m/FU</b>	<b>0.0080934</b>
	<b>Rumennite</b>	<b>Ib/FU</b>	<b>2.350849</b>
	<b>Ilmenite</b>	<b>Ib/FU</b>	<b>78.06144</b>
	<b>Air</b>	<b>Ib/FU</b>	<b>1.072732</b>
	<b>Coke</b>	<b>Ib/FU</b>	<b>0.32182</b>
	<b>Sodium hydroxide</b>	<b>Ib/FU</b>	<b>0.011026</b>
	<b>SiAl</b>	<b>Ib/FU</b>	<b>0.001838</b>
	<b>Fuel</b>	<b>Ib/FU</b>	<b>0.053637</b>
	<b>Starch</b>	<b>Ib/FU</b>	<b>39117.03</b>
	<b>Soda ash</b>	<b>Ib/FU</b>	<b>0.209911</b>
	<b>Limestone</b>	<b>Ib/FU</b>	<b>2.623886</b>
	<b>Bauxite</b>	<b>Ib/FU</b>	<b>4.653024</b>
		<b>Ib/FU</b>	<b>83.96435</b>
	<b>Air Emissions</b>		
	<b>CO</b>	<b>Ib/FU</b>	<b>0.005387</b>
	<b>PM</b>	<b>Ib/FU</b>	<b>0.00298</b>
	<b>SOx</b>	<b>Ib/FU</b>	<b>0.001525</b>
	<b>VOC</b>	<b>Ib/FU</b>	<b>0.004981</b>
	<b>Benzene</b>	<b>Ib/FU</b>	<b>0.006263</b>
	<b>Toluene</b>	<b>Ib/FU</b>	<b>0.03401</b>
	<b>Ethylbenzene</b>	<b>Ib/FU</b>	<b>0.234812</b>
	<b>Xylene</b>	<b>Ib/FU</b>	<b>0.045559</b>
	<b>Cumene</b>	<b>Ib/FU</b>	<b>0.005872</b>
	<b>Phenol</b>	<b>Ib/FU</b>	<b>0.000249</b>
	<b>Heavy Aromatics</b>	<b>Ib/FU</b>	<b>0.007122</b>
	<b>NOx</b>	<b>Ib/FU</b>	<b>0.000025</b>
	<b>PM10</b>	<b>Ib/FU</b>	<b>0.000889</b>
	<b>Acetaldehyde</b>	<b>Ib/FU</b>	<b>0.000825</b>
	<b>Ethylene</b>	<b>Ib/FU</b>	<b>0.000018</b>
	<b>HCN</b>	<b>Ib/FU</b>	<b>0.000033</b>
	<b>Chlorine</b>	<b>Ib/FU</b>	<b>0.001</b>
	<b>MEK</b>	<b>Ib/FU</b>	<b>0.000153</b>
	<b>Isobutynaldehyde</b>	<b>Ib/FU</b>	<b>0.000052</b>
	<b>Acetone</b>	<b>Ib/FU</b>	<b>0.000053</b>
	<b>Ammonia</b>	<b>Ib/FU</b>	<b>2.1E-07</b>
	<b>Fluorine</b>	<b>Ib/FU</b>	<b>0.000096</b>
	<b>Lead</b>	<b>Ib/FU</b>	<b>0.00003</b>

MIBK	0	0	0.000383	0.002559
Isopropyl alcohol	0	0	0	0
MAK	0.010193	0	0	0
Aromatic hydrocarbons	0.000438	0	0	0
Butyl acetate	0.000442	0.001316	0.0003828	0
Naphtha	0.001281	0	0	0
Propyl acetate	0	0	0	0
MPK	0	0	0	0
Butyl cellosolve	0	0.00489	0	0
Hexyl acetate	3.523738	1.822771	2.08293	5.074648
CO2	0.000798	0.000413	0.000421	0.00115
Hexane	0.001028	0.000532	0.000542	0.001461
Heptane	0.000987	0.000356	0.000363	0.00099
Octane	0.000145	0.000075	0.000076	0.000209
C-7 cycloparaffins	0.000053	0.000027	0.000028	0.000076
C-8 cycloparaffins	0.000498	0.000258	0.000263	0.000718
Pentane	0.003311	0.001713	0.001746	0.004769
Methane	0.00057	0.000295	0.0003	0.00082
Ethane	0.000893	0.000462	0.000471	0.001287
Propane	0.000708	0.000366	0.000373	0.001019
n-Butane	0.000035	0.000018	0.000019	0.000051
Iso-Butane	0.000251	0.00013	0.000132	0.000362
Formaldehyde	0.039831	0.020604	0.021004	0.057362
Hydrocarbons	0.000232	0.00012	0.000122	0.000334
Aldehydes	0.000295	0.000153	0.000156	0.000425
Organic Acids	0.000041	0.000029	0.0000303	0.0000029
Kerosene	1.6E-06	0.000022	0	0
Carbon tetrachloride	0.000598	0.000598	0.000284	0.001337
Chloroform	0.000284	0.000284	0.000637	0.002999
Ethyl chloride	0.000637	0.000637	0.001647	0.007745
Ethylene dichloride	0.001647	0.001647	0.000487	0.00229
Trichloroethane	0.000487	0.000487	0.000303	0.001428
Vinyl chloride	0.000303	0.000303	0.001132	0.000083
Hydrochloric acid	0.001132	0.001132	0.001111	0.000083
Sulfuric acid	0	0	0	0
Propylene	0	0	0	0
1,2-butylene	0	0	0	0
2-nitropropane	0	0	0	0
Acetonitrile	0	0	0	0
Bromochlorodifluoromethane	0	0	0	0
Bromotrifluoromethane	0	0	0	0

Dichlorodifluoromethane	0	Ib/FU
Methanol	0	Ib/FU
Naphthalene	0	Ib/FU
Nitric acid	0	Ib/FU
Butyl alcohol	0	Ib/FU
Nitroethane	0.03424	Ib/FU
Aliphatic hydrocarbons	0	Ib/FU
<b>Wastewater Emissions</b>		
Wastewater	34.85286	Ib/lb
WW Reinj'd	1.939381	Ib/lb
WW Discharg.	0.857607	Ib/lb
WW Injected	0.281159	Ib/lb
Arsenic	3.5E-07	Ib/lb
Benzene	8.6E-06	Ib/lb
Boron	0.000094	Ib/lb
Sodium	0.172821	Ib/lb
Chloride	0.136437	Ib/lb
Mobile Ions	0.418408	Ib/lb
Oil and Grease	0.00426	Ib/lb
Cadmium	2.9E-06	Ib/lb
Chromium	2.6E-07	Ib/lb
Mercury	6.6E-06	Ib/lb
Thallium	6.3E-06	Ib/lb
Sulfuric Acid	3.2E-06	Ib/lb
Iron	0.000283	Ib/lb
Dissolved Solids		Ib/FU
Suspended Solids		Ib/FU
COD		Ib/FU
Phenol		Ib/FU
Sulfide		Ib/FU
Oil		Ib/FU
Acid		Ib/FU
Metals		Ib/FU
BOD	4.5E-06	Ib/FU
Vanadium	1.4E-06	Ib/FU
Zinc	1.4E-06	Ib/FU
Copper	0.000041	Ib/FU
Aluminum	0.00002	Ib/FU
Titanium dioxide	0.004455	Ib/FU
Lead	0.000061	Ib/FU

<b>Magnesium</b>	<b>4.1E-09</b>	<b>0.000328</b>	<b>0.593655</b>	<b>0.551683</b>	<b>62.13212</b>
<b>Chlorine</b>					<b>0.039165</b>
<b>Ammonia</b>					<b>0</b>
<b>Hydrogen cyanide</b>					<b>0</b>
<b>Solid Wastes</b>	<b>lb/lb</b>	<b>0.27641</b>	<b>0.000476</b>	<b>0.07913</b>	<b>0.000284</b>
<b>Solid Wastes</b>	<b>lb/lb</b>	<b>0.000132</b>			
<b>Hazardous Wastes</b>	<b>lb/lb</b>				
<b>Fly Ash</b>					<b>1.9E-09</b>
<b>Bottom Ash</b>					<b>5.3E-10</b>
<b>Slag</b>					<b>2.0E-10</b>
<b>FGD Solids</b>					<b>7.2E-10</b>
<b>U236</b>					<b>5.0E-09</b>
<b>U238</b>					<b>3.3E-12</b>
<b>U235</b>					<b>4.2E-11</b>
<b>Pu (fissile)</b>					<b>3.4E-11</b>
<b>Pu (nonfissile)</b>					<b>1.3E-11</b>
<b>Fission Products</b>					<b>2.4E-11</b>
<b>2-nitropropane</b>				<b>0</b>	<b>0</b>
<b>Acetaldehyde</b>				<b>0</b>	<b>0</b>
<b>Acetone</b>				<b>0</b>	<b>0</b>
<b>Acetonitrile</b>				<b>0</b>	<b>0</b>
<b>Formaldehyde</b>				<b>0</b>	<b>0</b>
<b>Methanol</b>				<b>0</b>	<b>0</b>
<b>Naphthalene</b>				<b>0</b>	<b>0</b>
<b>Nitric acid</b>				<b>0</b>	<b>0</b>
<b>Ammonia</b>				<b>0</b>	<b>0</b>
<b>Hydrogen cyanide</b>				<b>0</b>	<b>0</b>

### Alt. Primer & Thinner CARC System Life Cycle Inventory Summary Results

Notes: [REDACTED] = User Input

Table C-6

Inventory numbers for individual CARC System components do not include emissions and energy or materials consumption for electric power generation. The "Baseline CARC System" numbers do include electric power generation data.

LCI Components	Units	Thinned TC Top Coat Quantity	Primer Quantity	Prim. Pt. A Quantity	Prim. Pt. B Quantity	Baseline CARC System Units	Baseline CARC System Quantity
Usage Rate	ft <sup>2</sup> /gal.	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
Volumetric Mixing Ratio	CARC/thin.	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
Volumetric Mixing Ratio	Pt. A:Pt. B	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
Specific Gravity		[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
Unit Weight	lb/gal.	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
Usage Rate	lb/ft <sup>2</sup>	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]	[REDACTED]
Functional Unit (FU)		0.05145	0.001117	0.028514	0.004706	ft <sup>2</sup>	[REDACTED]
<b>Resource and Energy Consumption</b>							
Electricity	BTU/lb	10813.84	3020.153	4274.133	12891.53	BTU/FU	742279.6
Natural gas	BTU/lb	177054.9	48511.73	88971.35	215194.5	BTU/FU	12788675
Steam	BTU/lb	6454.894	275.1648	805.3541	3130.39	BTU/FU	498327.6
Water	lb/lb	486.9277	153.8514	386.9551	957.8537	lb/FU	40765.31
Crude oil	lb/lb	33.01711	17.0792	15.18903	39.80183	lb/FU	2338.21
Oxygen	lb/lb	0.078344	0.097628	0.214204	0.286878	lb/FU	11.50356
Refinery gases	lb/lb	1.234477	0.192075	0	0	lb/FU	63.72835
Cobalt oxide	lb/lb	0.0195	0.0195	0	0	lb/FU	1.003275
Chrome oxide	lb/lb	0.0885	0.0885	0	0	lb/FU	4.553325
Silica	lb/lb	0.26	0.26	0	0	lb/FU	13.377
Iron ore	lb/lb	0.023108	0.023108	0	0	lb/FU	1.341152
Magnetite	lb/lb	0.007703	0.007703	0	0	lb/FU	0.396294
Magnesium ore	lb/lb	0.043719	0.043719	0	0	lb/FU	2.249343
Sodium Chloride	lb/lb	0.504494	0.504494	0.35447	1.573775	lb/FU	43.46975
Phosphoric acid	lb/lb	0.000926	0.000926	0.192582	0	lb/FU	0.047642
Sulfuric acid	lb/lb	0.052292	0.052292	0.000044	0	lb/FU	8.181103
Sulfur dioxide	lb/lb	0.000033	0.000033	0	0	lb/FU	0.002242
Hydrocarbons C8 to C10	lb/lb	0	0	0	0	lb/FU	0.016979
Proprietary Primer Ingredients	lb/lb	0	0	0	0	lb/FU	0
Chlorine	lb/lb	0	0	0.332521	1.120572	lb/FU	14.75491
Coal	lb/lb	0	0	0	0	lb/FU	0.000015
Phosphate ore	lb/lb	0	0	0	0	lb/FU	0



MIBK	Ib/FU	0	0	0	0	0	0
Isopropyl alcohol	Ib/FU	0	0	0	0	0	0
MIAK	Ib/FU	0.010193	0	0	0	0	0
Aromatic hydrocarbons	Ib/FU	0.000438	0	0	0	0	0.524453
Butyl acetate	Ib/FU	0.000442	0.001316	0	0	0	0.060582
Naphtha	Ib/FU	0.001281	0	0	0	0	0.024192
Propyl acetate	Ib/FU	0	0	0	0	0	0.065909
MPK	Ib/FU	0	0	0	0	0	0
Butyl cellosolve	Ib/FU	0	0	0	0	0	0
Hexyl acetate	Ib/FU	0	0.00489	0	0	0	0.00546
CO2	Ib/FU	3.523738	1.822771	1.997999	4.247838	0.000963	260.2931
Hexane	Ib/FU	0.000798	0.000413	0.000367	0.000367	0.000367	0.056546
Heptane	Ib/FU	0.001028	0.000532	0.000473	0.001239	0.000473	0.072806
Octane	Ib/FU	0.000687	0.000356	0.000316	0.000829	0.000316	0.048687
C-7 cycloparaffins	Ib/FU	0.000145	0.000075	0.000087	0.000175	0.000087	0.010257
C-8 cycloparaffins	Ib/FU	0.000053	0.000027	0.000024	0.000084	0.000024	0.00375
Pentane	Ib/FU	0.000499	0.000258	0.000229	0.000601	0.000229	0.035307
Methane	Ib/FU	0.003311	0.001713	0.001523	0.003992	0.001523	0.234511
Ethane	Ib/FU	0.00057	0.000295	0.000282	0.000687	0.000282	0.040333
Propane	Ib/FU	0.000893	0.000462	0.000411	0.001077	0.000411	0.06327
n-Butane	Ib/FU	0.000708	0.000368	0.000326	0.000853	0.000326	0.050125
Iso-Butane	Ib/FU	0.000035	0.000018	0.000016	0.000043	0.000016	0.0025
Formaldehyde	Ib/FU	0.000251	0.000013	0.000118	0.000379	0.000118	0.018151
Hydrocarbons	Ib/FU	0.039831	0.026804	0.018324	0.048016	0.018324	2.820768
Aldehydes	Ib/FU	0.000232	0.00012	0.000107	0.000279	0.000107	0.016414
Organic Acids	Ib/FU	0.000295	0.000153	0.000136	0.000356	0.000136	0.020891
Kerosene	Ib/FU	0	0	0	0	0	3.9E-09
Carbon tetrachloride	Ib/FU	0	0	0	0	0	0
Chloroform	Ib/FU	0	0	0	0	0	0
Ethyl chloride	Ib/FU	0	0	0	0	0	0
Ethylene dichloride	Ib/FU	0	0	0	0	0	0
Trichloroethane	Ib/FU	0	0	0	0	0	0
Vinyl chloride	Ib/FU	0	0	0	0	0	0
Hydrochloric acid	Ib/FU	1.6E-06	0	0	0	0	1.5E-07
Sulfuric acid	Ib/FU	0	0	0	0	0	0.000129
Propylene	Ib/FU	0.000022	0	0	0	0	5.1E-08
1,2-butylene	Ib/FU	0	0	0	0	0	4.7E-07
2-nitropropane	Ib/FU	0	0	0	0	0	1.8E-06
Acetonitrile	Ib/FU	0	0	0	0	0	2.2E-06
Bromochlorodifluoromethane	Ib/FU	0	0	0	0	0	8.3E-06
Bromotrifluoromethane	Ib/FU	0	0	0	0	0	0

Dichlorodifluoromethane	Ib/FU	0.001102
Methanol	Ib/FU	4.0E-08
Naphthalene	Ib/FU	0.000019
Nitric acid	Ib/FU	0.000643
Butyl alcohol	Ib/FU	5.5E-06
Nitroethane	Ib/FU	0.041712
Aliphatic hydrocarbons	Ib/FU	0.003869
	Ib/FU	0
	Ib/FU	0.000234
	Ib/FU	4.0E-08
	Ib/FU	0.000137
	Ib/FU	1.2E-06
	Ib/FU	0.000822
	Ib/FU	0
	Ib/FU	0
	Ib/FU	0.001463
	Ib/FU	0
	Ib/FU	0
	Ib/FU	0
	Ib/FU	2985.152
	Ib/FU	137.3419
	Ib/FU	60.73412
	Ib/FU	19.91113
	Ib/FU	0.000025
	Ib/FU	0.338934
	Ib/FU	0.129343
	Ib/FU	0.35E-07
	Ib/FU	1.6E-07
	Ib/FU	4.3E-07
	Ib/FU	3.9E-06
	Ib/FU	0.00001
	Ib/FU	0.000084
	Ib/FU	0.000219
	Ib/FU	0.208334
	Ib/FU	0.079504
	Ib/FU	0.089397
	Ib/FU	0.172821
	Ib/FU	0.093199
	Ib/FU	1.939361
	Ib/FU	0.857607
	Ib/FU	0.443626
	Ib/FU	0.281159
	Ib/FU	0.145439
	Ib/FU	0.000182
	Ib/FU	0.000094
	Ib/FU	0.000426
	Ib/FU	0.002203
	Ib/FU	0.00426
	Ib/FU	0.216436
	Ib/FU	0.418408
	Ib/FU	0.138437
	Ib/FU	0.070577
	Ib/FU	0.000273
	Ib/FU	3.5E-08
	Ib/FU	0.000031
	Ib/FU	3.2E-07
	Ib/FU	0.000198
	Ib/FU	0.005135
	Ib/FU	0.000273
	Ib/FU	0.000031
	Ib/FU	3.2E-07
	Ib/FU	0.000198
	Ib/FU	6.0E-08
	Ib/FU	6.1E-08
	Ib/FU	2.9E-08
	Ib/FU	7.6E-08
	Ib/FU	0.000441
	Ib/FU	8.4E-08
	Ib/FU	7.2E-06
	Ib/FU	6.1E-07
	Ib/FU	2.1E-09
	Ib/FU	4.0E-09
	Ib/FU	3.4E-10
	Ib/FU	3.4E-10
	Ib/FU	1.2E-09
	Ib/FU	6.7E-10
	Ib/FU	6.7E-10
	Ib/FU	0.000213
	Ib/FU	0.000068
	Ib/FU	0.000068
	Ib/FU	0.000968
	Ib/FU	0.213034
	Ib/FU	0.000102
	Ib/FU	0.002905

Magnesium	<b>6.8E-09</b>	0.025758	Ib/FU	1.9E-07
Chlorine	0.025758	3.7E-07	Ib/FU	0.12121
Ammonia	3.7E-07	2.5E-08	Ib/FU	1.7E-08
Hydrogen cyanide	2.5E-08	Ib/FU	Ib/FU	1.2E-07
<b>Solid Wastes</b>				
<b>Solid Wastes</b>	Ib/lb	<b>0.27641</b>	<b>0.000476</b>	<b>0.442834</b>
<b>Hazardous Wastes</b>	Ib/lb	<b>0.000132</b>	<b>0.03398</b>	<b>1.513701</b>
Fly Ash				
Bottom Ash				
Slag				
FGD Solids				
U238				
U236				
U235				
Pu (fissile)				
Pu (nonfissile)				
<b>Fission Products</b>				
2-nitropropane		<b>0.001717</b>	<b>0.008079</b>	
Acetaldehyde		<b>0.002214</b>	<b>0.010418</b>	
Acetone		<b>0.001188</b>	<b>0.005591</b>	
Acetonitrile		<b>0.000989</b>	<b>0.004561</b>	
Formaldehyde		<b>0.000017</b>	<b>0.000008</b>	
Methanol		<b>0.001951</b>	<b>0.009182</b>	
Naphthalene		<b>1.4E-06</b>	<b>6.6E-06</b>	
Nitric acid		<b>0.000137</b>	<b>0.000643</b>	
Ammonia		<b>0.000003</b>	<b>0.000142</b>	
Hydrogen cyanide		<b>1.4E-06</b>	<b>6.6E-06</b>	

APPENDIX D  
ENVIRONMENTAL IMPACT EQUIVALENCY VALUE  
CALCULATIONS AND DECISIONS TREES

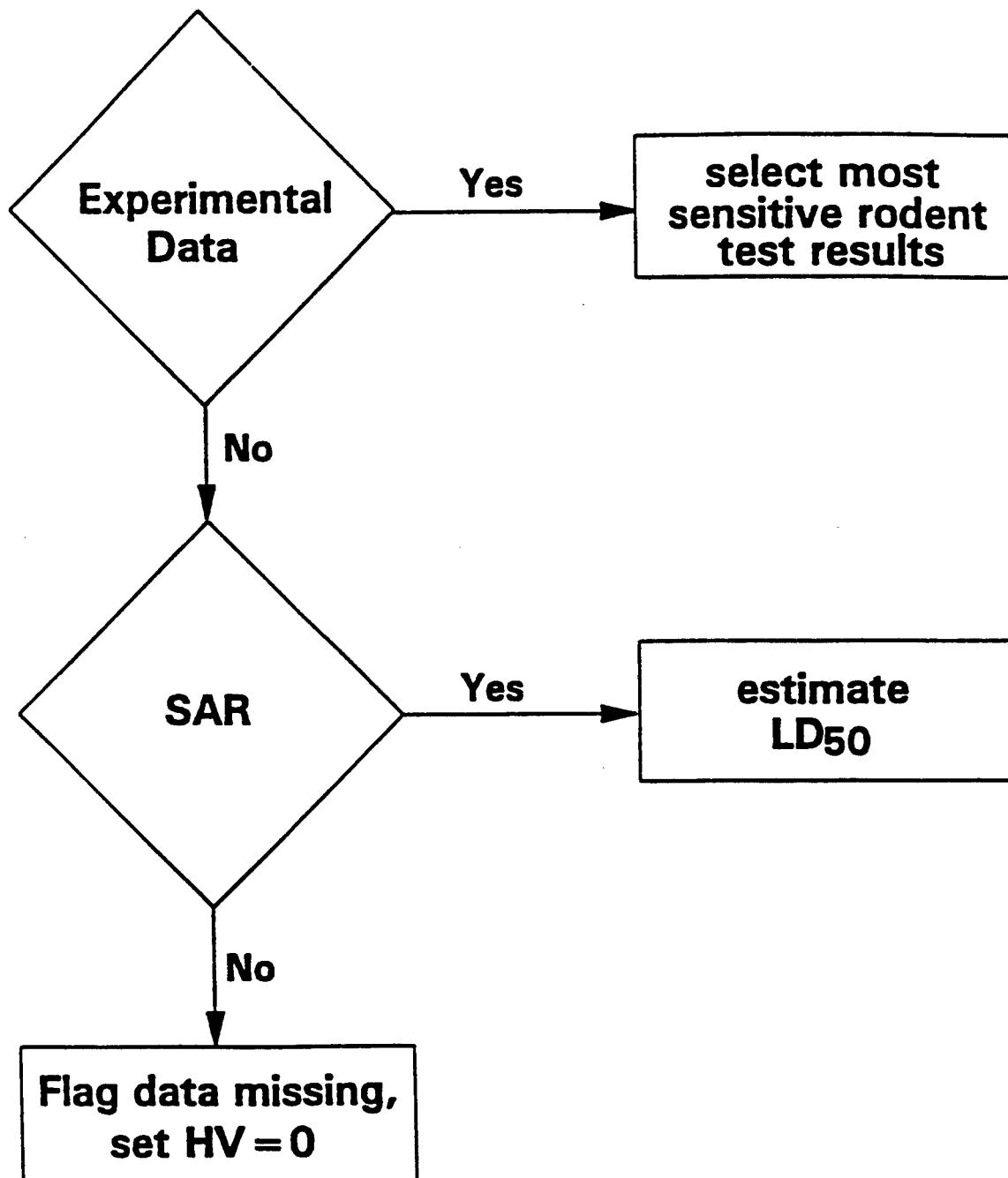


Figure D-1. Decision Tree for Oral LD<sub>50</sub> Data Selection (from EPA, 1994)

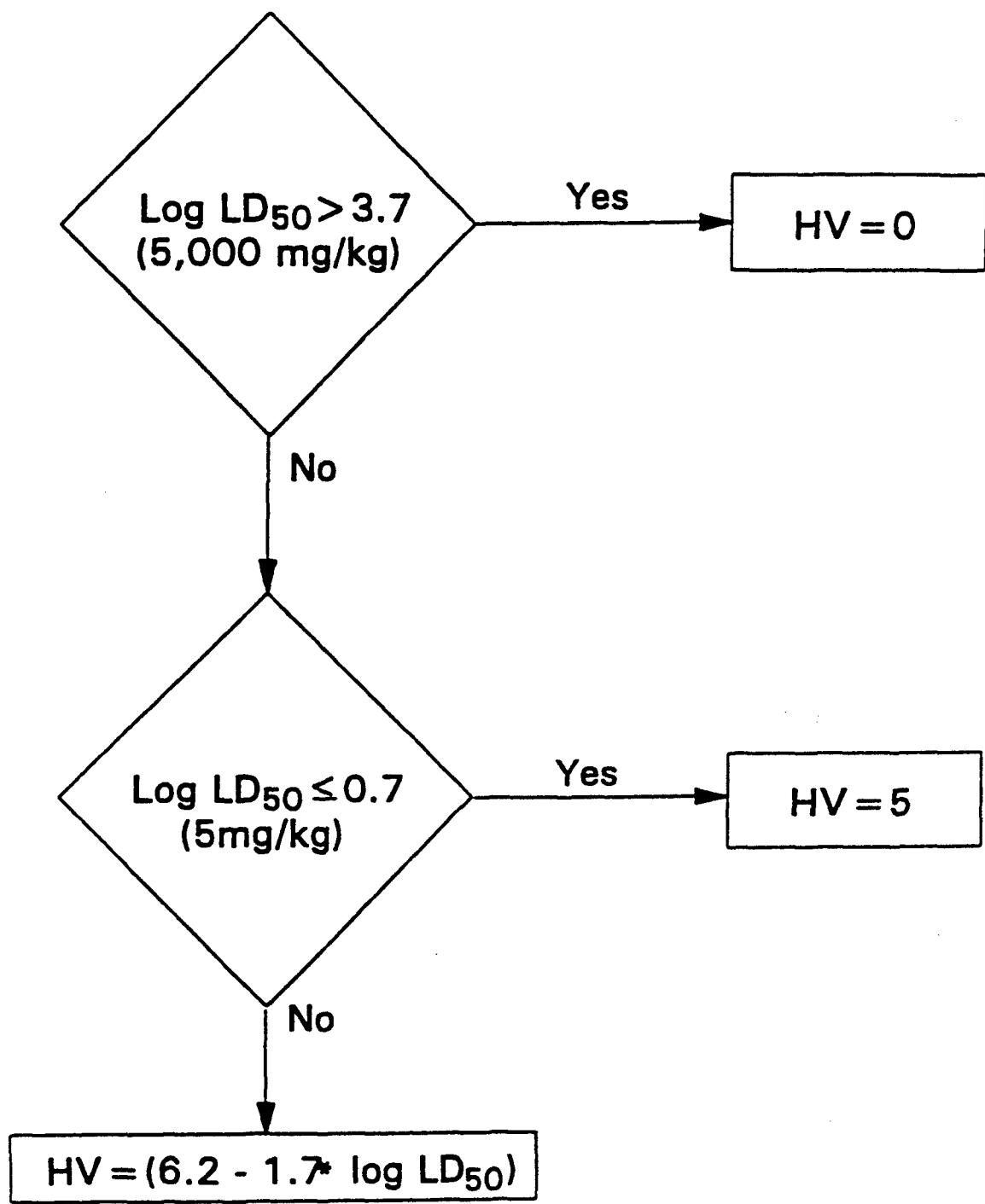


Figure D-2. Decision Tree for Oral LD<sub>50</sub> Hazard Value (from EPA, 1994)

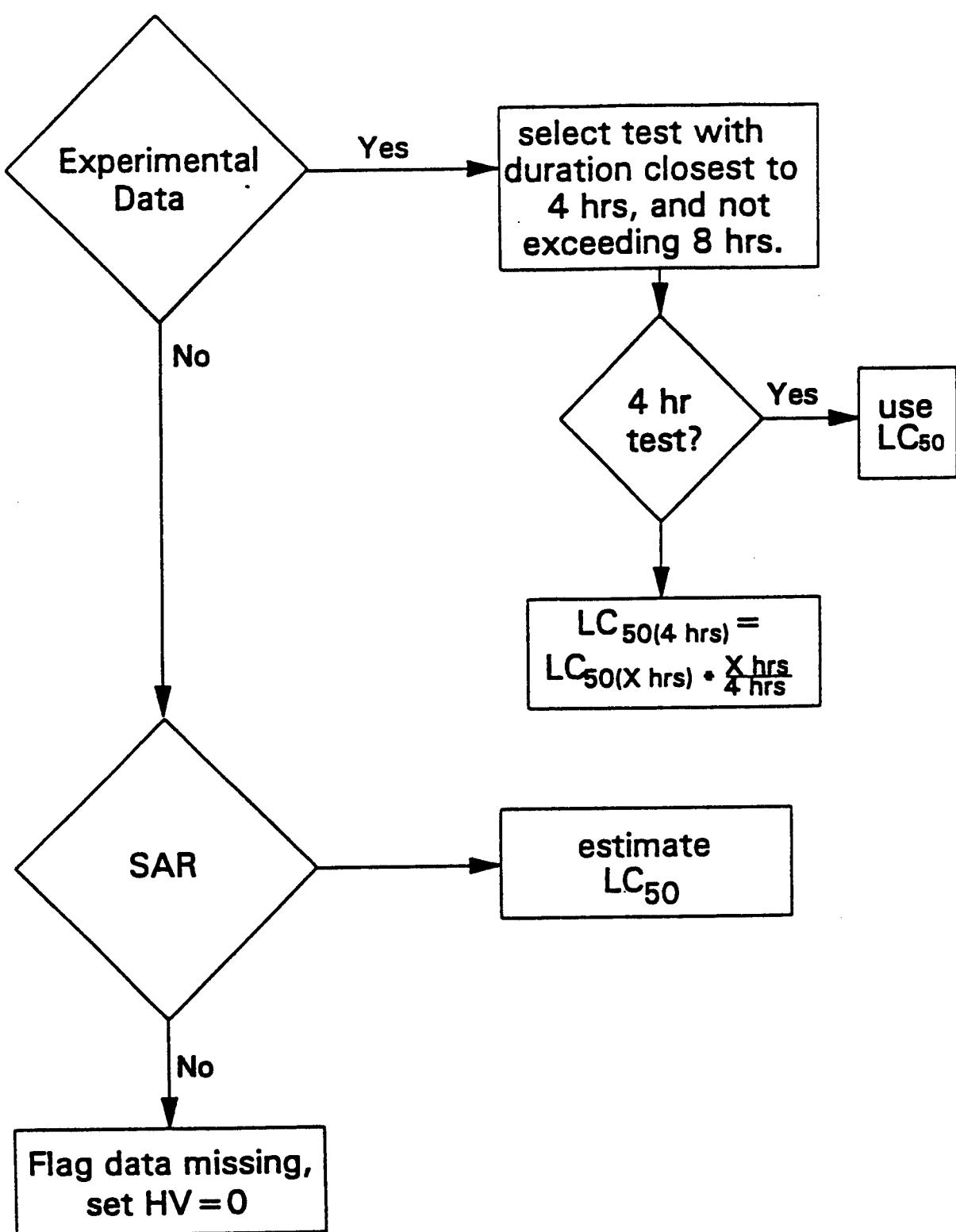


Figure D-3. Decision Tree for Inhalation LC<sub>50</sub> Data Selection  
 (from EPA, 1994)

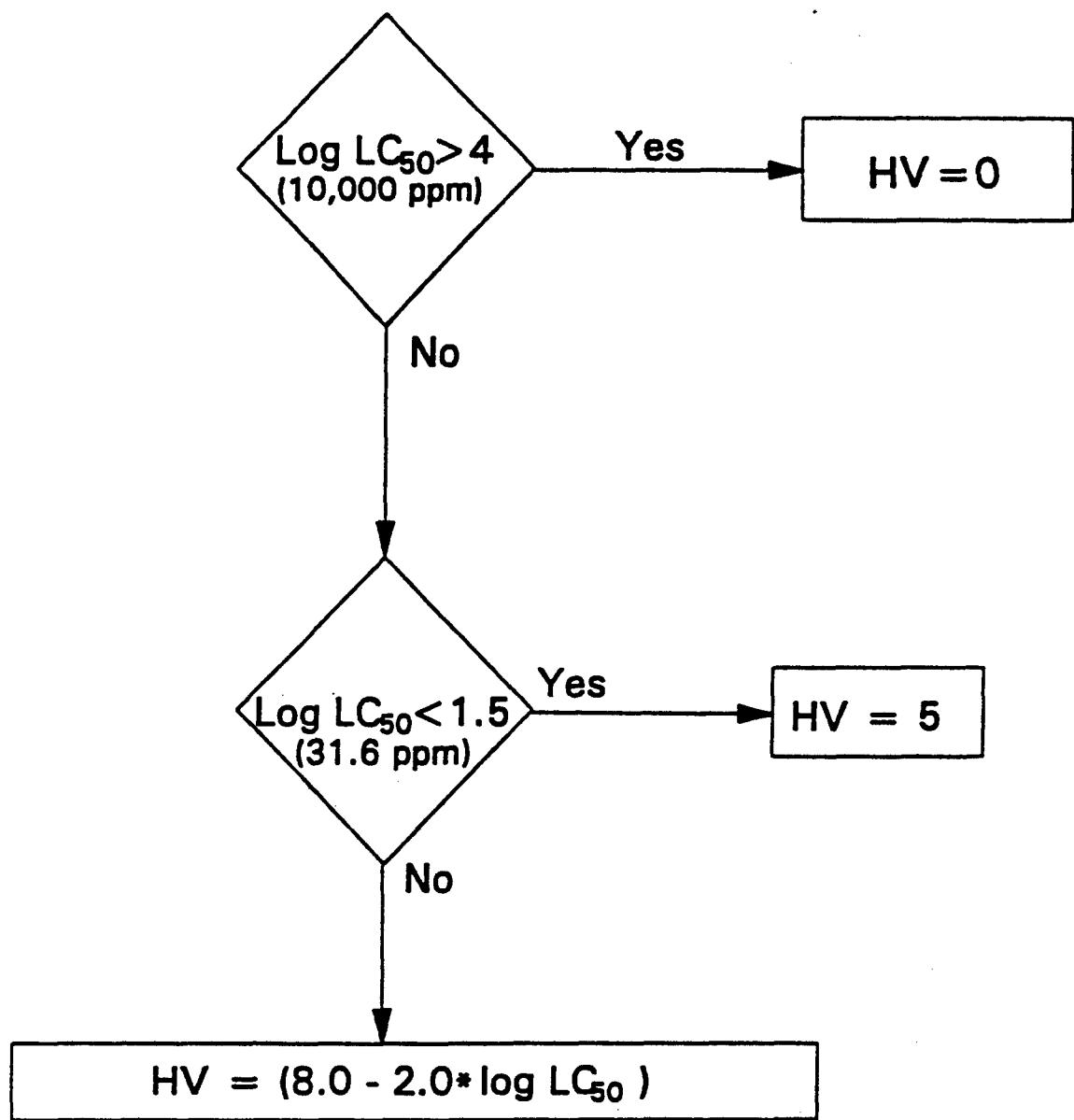
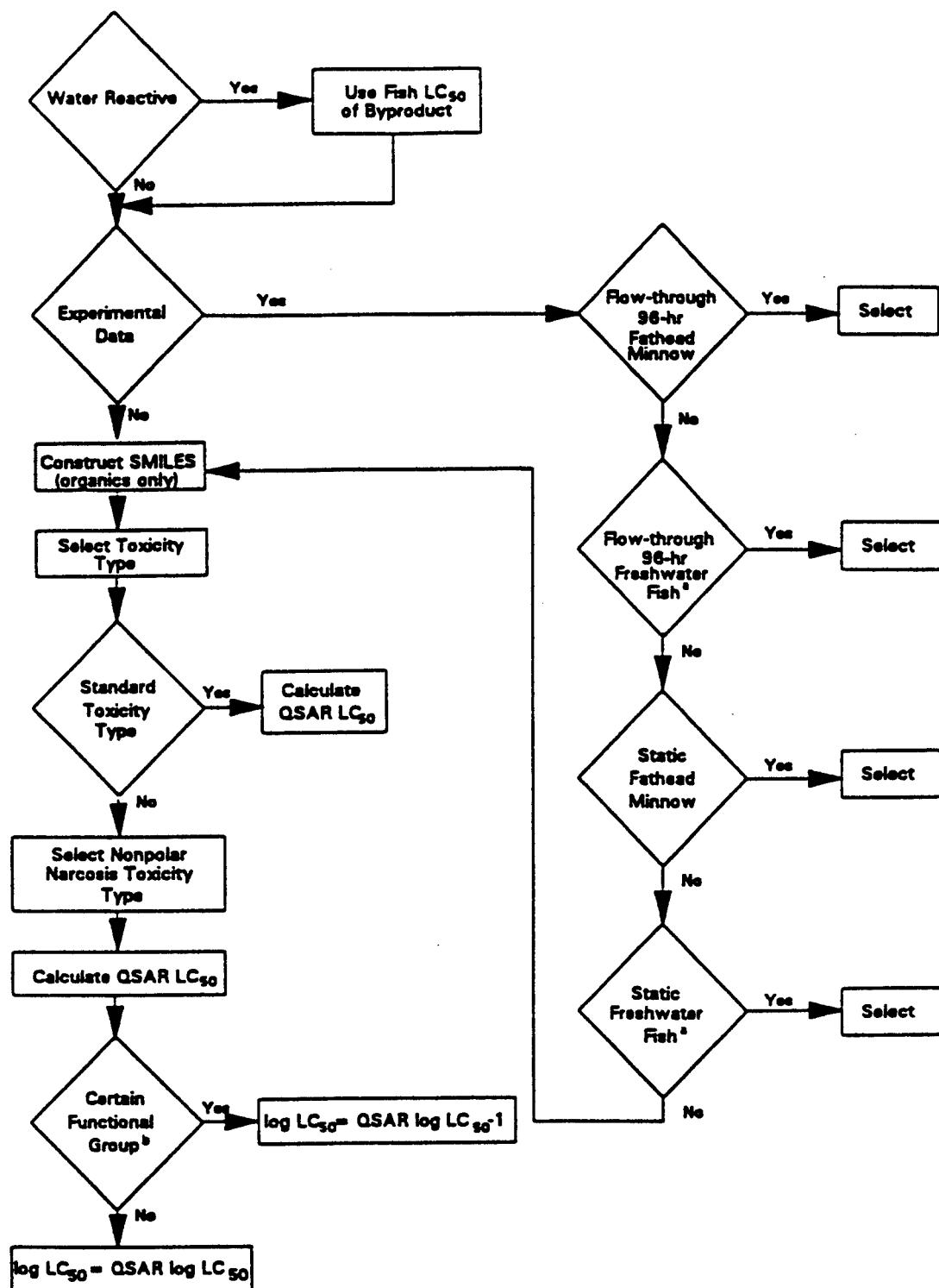


Figure D-4. Decision Tree for Inhalation LC<sub>50</sub> Hazard Values  
(from EPA, 1994)



<sup>a</sup>excluding trout

<sup>b</sup> includes good electrophiles, good nucleophiles, strong acids, chemicals with an aromatic ring, and certain reactive groups

Figure D-5. Decision Tree for Fish LC<sub>50</sub> Data Selection (from EPA, 1994)

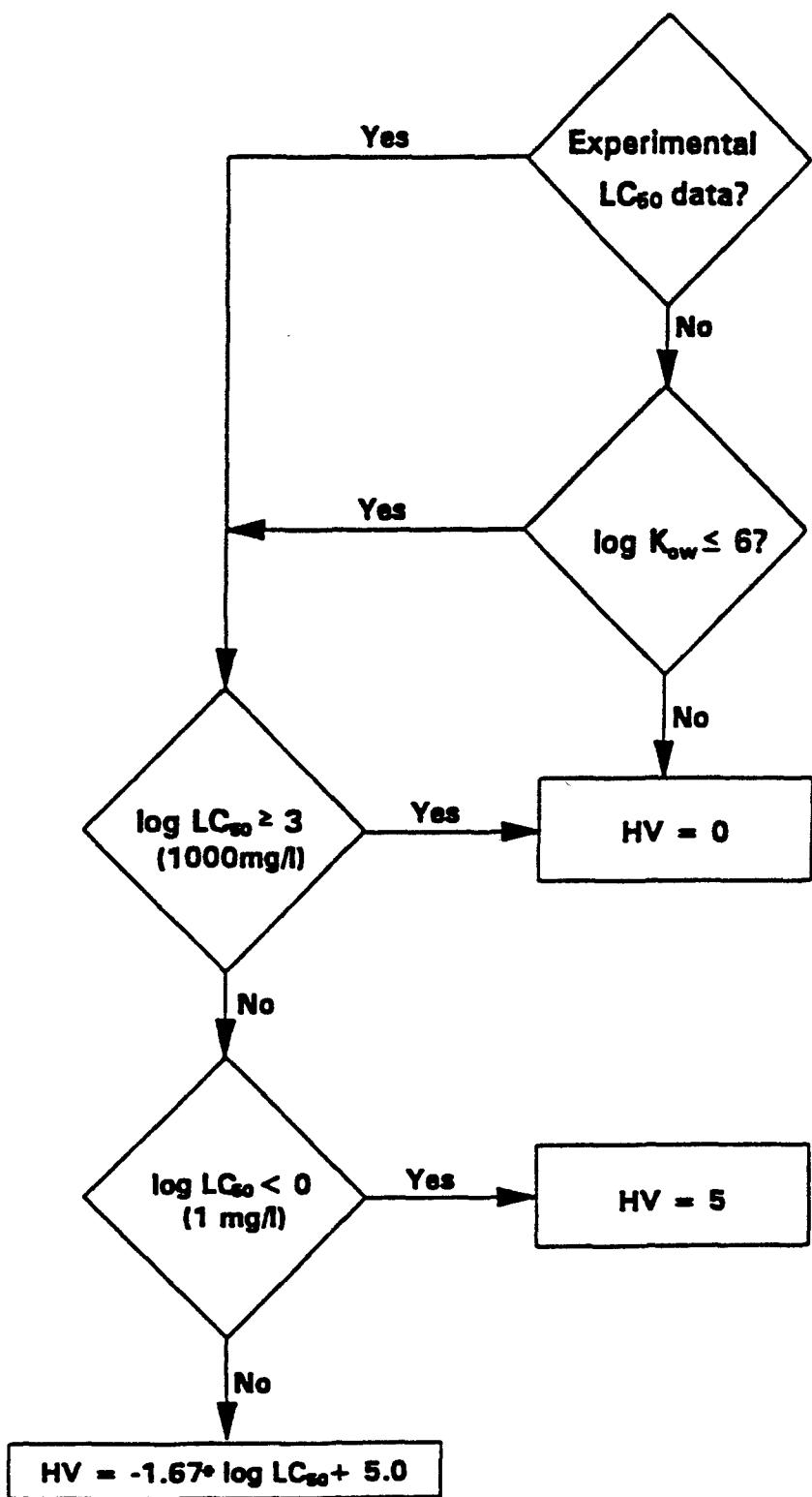


Figure D-6. Decision Tree for Aquatic LC<sub>50</sub> Hazard Value  
(from EPA, 1994)

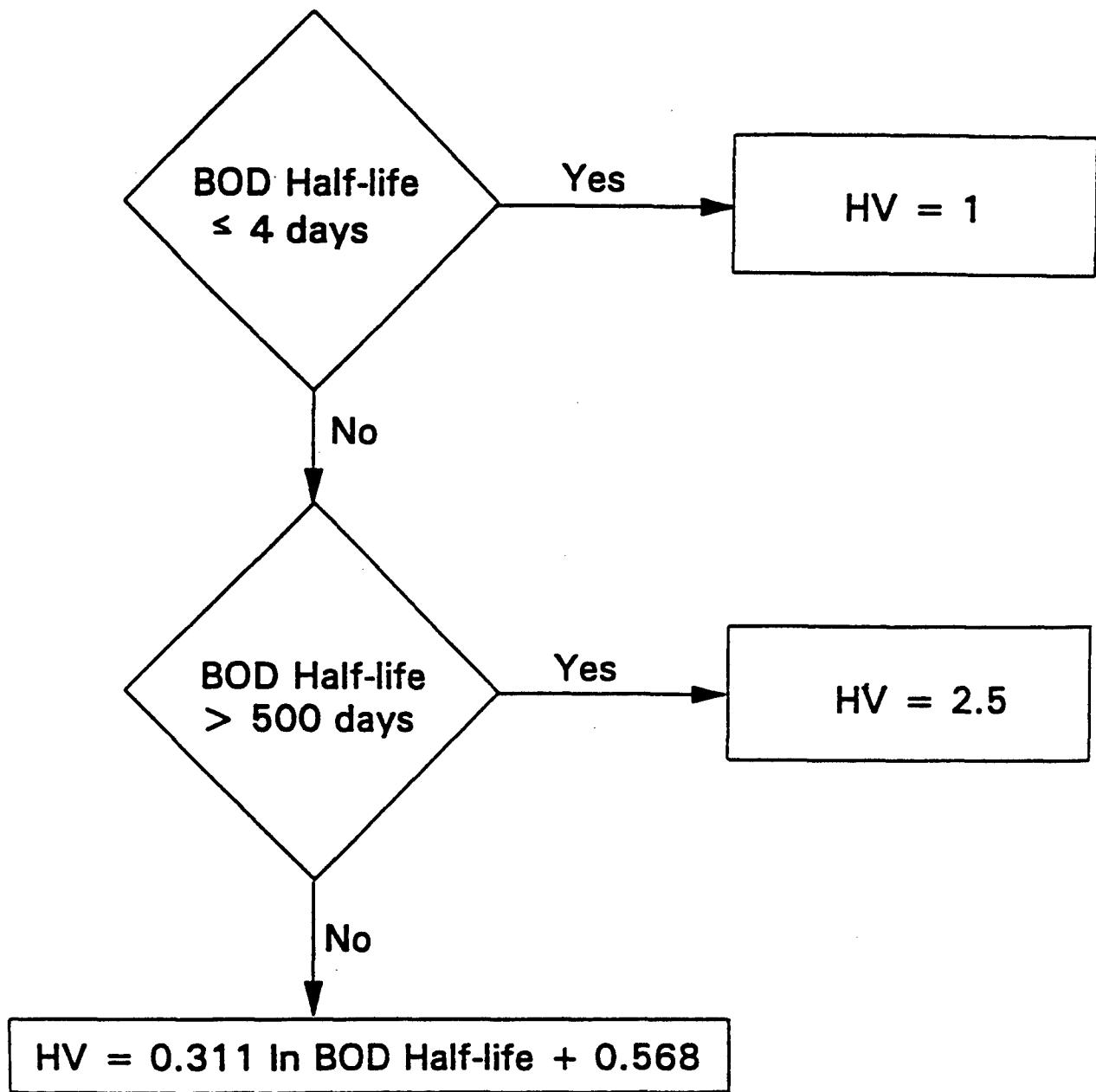


Figure D-7. Decision Tree for BOD Half-Life Hazard Value  
(from EPA, 1994)

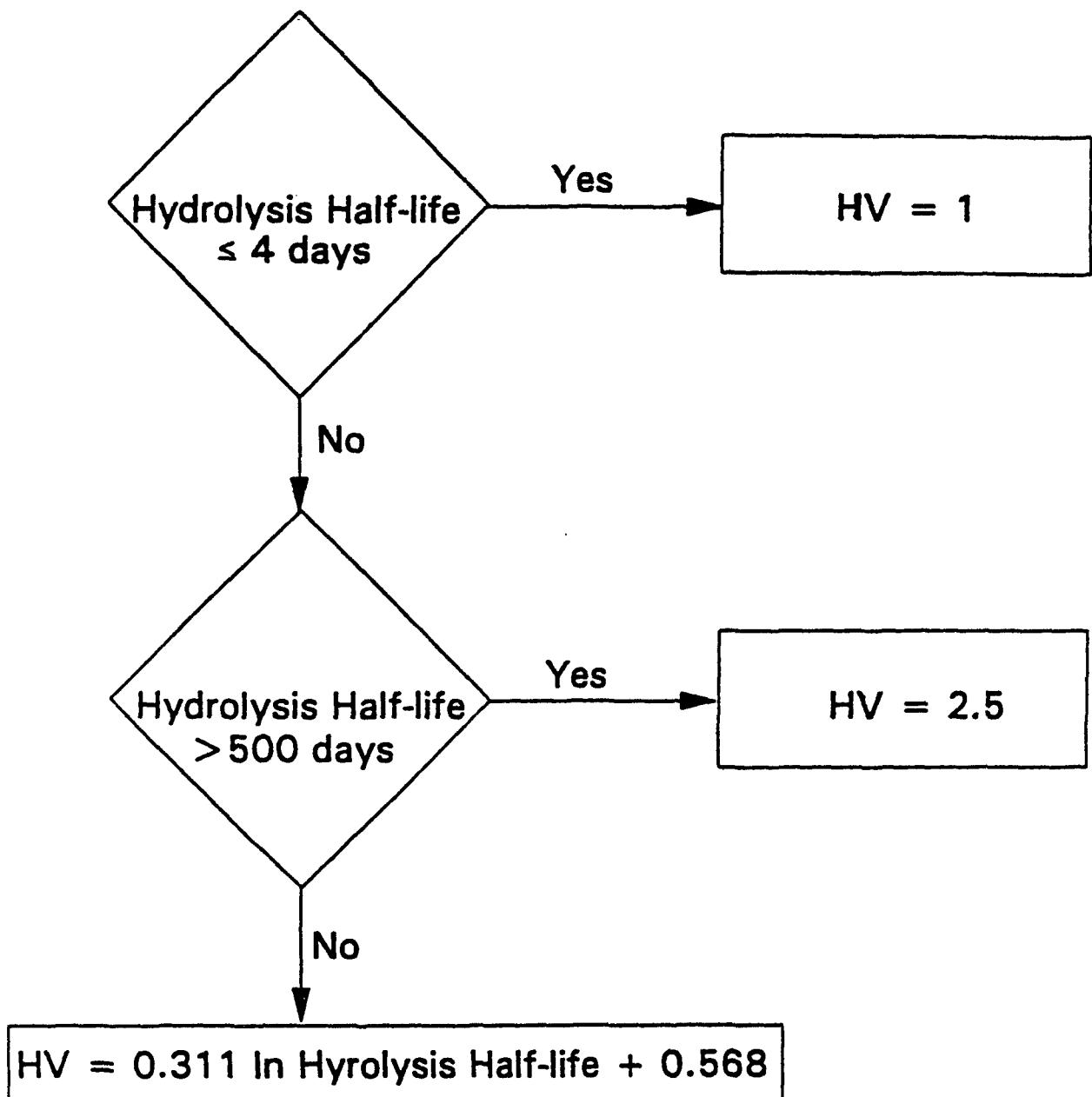


Figure D-8. Decision Tree for Hydrolysis Half-Life Hazard Value (from EPA, 1994)

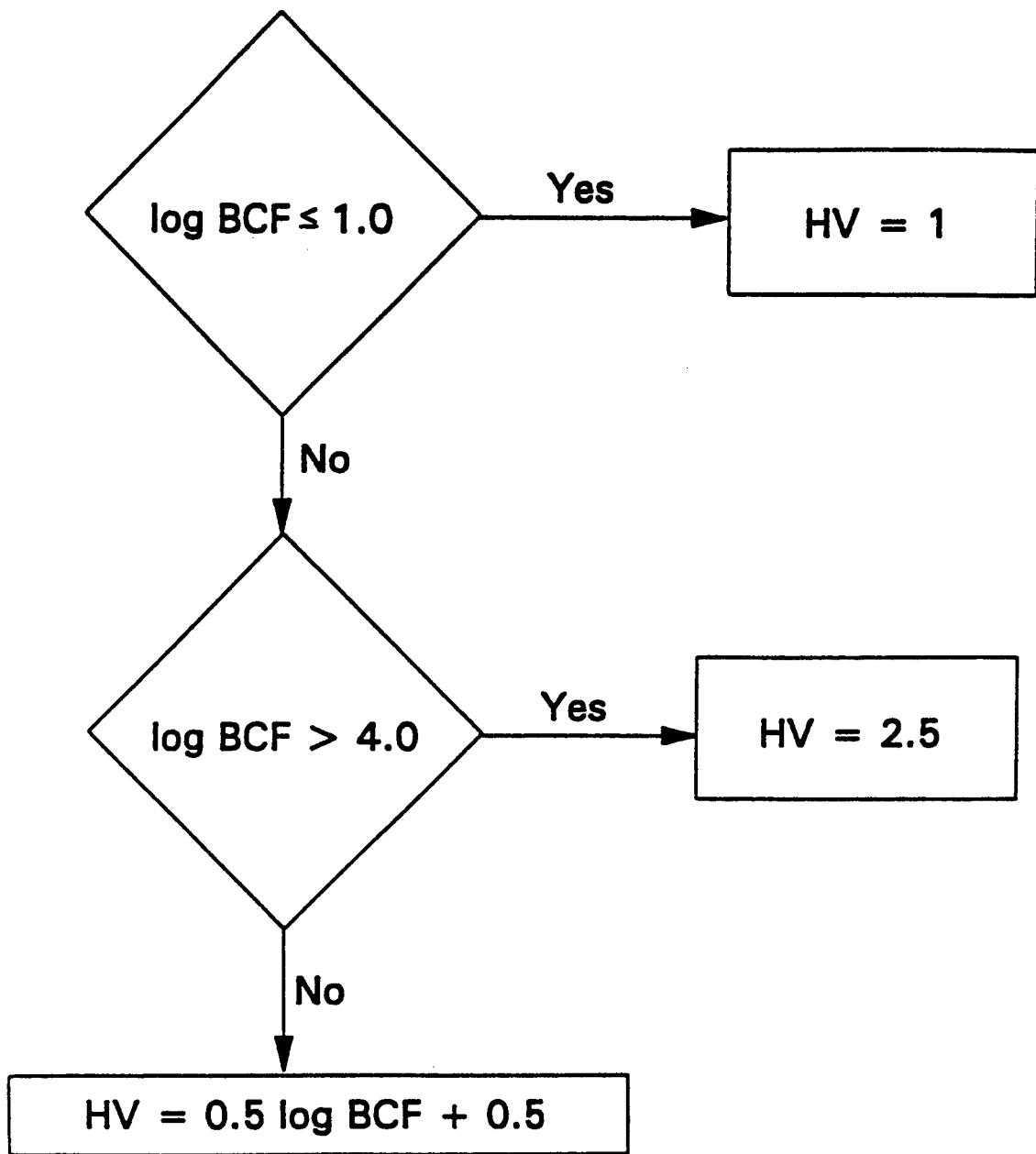


Figure D-9. Decision Tree for BCF Hazard Value (from EPA, 1994)

**BASELINE SYSTEM**

**D-10**

## LIFE CYCLE IMPACT VALUATION CALCULATIONS

CARCOPT	Scale	Issues ----->	AHP	Normalized Factored Score	Weighted Normalized Factored Score	Baseline Score
			Weighting Factor			► 0.843
GLOBAL	ODP	0.17983	1.090	0.347	0.220	0.843
	GLBLWRM	0.11328	1.013			
	FSLFUELS	0.02855	1.263			
REGIONAL	ACIDDEP	0.06253	1.198	0.276	0.237	0.843
	SMOG	0.13007	1.114			
	WTRUSE	0.01002				
LOCAL	TOXICITY	0.06155	2.150	0.040	0.026	0.843
	HUMAN	0.02052	3.799			
	ENVTERR	0.02052	1.280			
	ENVAQ	0.02507	1.577			
	LANDUSE					

**OZONE DEPLETION POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	ODP Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total ODP Score			0.003	1.090
Normalizing Factor			0.003	
CARBON TETRACHLORIDE	1.080	0.003	0.003	1.000
DICHLORODIFLUOROMETHANE	1.000	0.000	0.000	0.000
TRICHLOROETHANE (METHYL CHLOROFORM)	0.120	0.002	0.000	0.090

**GLOBAL WARMING POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	GWP Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total GWP Score			304.229	1.013
Normalizing Score			300.337	
CARBON TETRACHLORIDE	1300	0.003	3.663	0.012
CO2	1	300.337	300.337	1.000
DICHLORODIFLUOROMETHANE	7100	0.000	0.000	0.000
TRICHLOROETHANE	100	0.002	0.229	0.001

## RESOURCE DEPLETION IMPACT CALCULATIONS

CHEMICAL NAME	RESOURCE DEPLETION	Inventory		Normalized
	Equiv. Factor	Value lb/FU	Factored Score	Factored Score
Total Resource Depetion Score			13,906.073	1.263
Normalizing Score			11,010.628	
BAUXITE	4	83.964	335.857	0.031
CHROME OXIDE	2	4.553	9.107	0.001
COAL	3	0.292	0.875	0.000
COBALT OXIDE	3	1.003	3.010	0.000
IRON ORE	3	1.282	3.845	0.000
LIMESTONE	1	4.653	4.653	0.000
MAGNESIUM ORE	1	2.249	2.249	0.000
NATURAL GAS	4	602.895	2,411.581	0.219
PETROLEUM (CRUDE OIL)	4	2,752.657	11,010.628	1.000
PHOSPHATE ROCK	3	2.092	6.276	0.001
SALT (SODIUM CHLORIDE)	1	43.084	43.084	0.004
SILICA	1	13.657	13.657	0.001
SODA ASH	1	2.624	2.624	0.000
THALLIUM	4		0.000	0.000
TITANIUM	3	8.412	25.235	0.002
URANIUM (235, 236, 238)	3	0.000	0.000	0.000
WATER INPUT	NA	43,695.190	0.000	0.000
ZINC	4	8.347	33.390	0.003

NA = Not Available

**ACIDIFICATION POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	Acid. Pot.	Inventory	Normalized	
	Equiv. Factor	Value lb/FU	Factored Score	Factored Score
Total Acid. Pot. Score			25.855	1.198
Normalizing Score			21.584	
AMMONIA	1.880	0.000	0.000	0.000
HYDROCHLORIC ACID	0.880	0.001	0.001	0.000
NOX	0.700	6.099	4.270	0.198
SOX	1.000	21.584	21.584	1.000

**PHOTOCHEMICAL OXIDANT POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	POCP Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total POCP Score			6.639	1.114
Normalizing Factor			5.959	
ACETALDEHYDE	0.527	0.089	0.047	0.008
ACETONE	0.178	0.008	0.001	0.000
ALDEHYDES	0.443	0.019	0.009	0.001
AROMATIC HYDROCARBONS (C8-C10)	0.761	0.023	0.017	0.003
BENZENE	0.189	0.203	0.038	0.006
BUTANE (n-)	0.410	0.059	0.024	0.004
BUTANE (iso-)	0.315	0.003	0.001	0.000
BUTYL ACETATE (n-)	0.323	0.150	0.048	0.008
BUTYL ALCOHOL	0.196	0.034	0.007	0.001
CHLOROFORM	0.021	0.001	0.000	0.000
ETHANE	0.082	0.047	0.004	0.001
ETHYL BENZENE	0.593	0.002	0.001	0.000
ETHYLENE	1.000	0.003	0.003	0.000
HEPTANE (n-)	0.529	0.086	0.045	0.008
HEXANE (n-)	0.421	0.067	0.028	0.005
METHANE	0.007	0.276	0.002	0.000
METHANOL	0.123	0.000	0.000	0.000
METHYL ETHYL KETONE	0.473	0.059	0.028	0.005
METHYL ISOAMYL KETONE	0.326	0.524	0.171	0.029
METHYL ISOBUTYL KETONE	0.326	0.023	0.008	0.001
METHYL PROPYL KETONE	0.326	0.000	0.000	0.000
OCTANE (n-)	0.493	0.057	0.028	0.005
PENTANE (n-)	0.408	0.042	0.017	0.003
PROPANE	0.420	0.074	0.031	0.005
PROPYL ACETATE	0.218	0.000	0.000	0.000
PROPYLENE	1.030	0.000	0.000	0.000
TOLUENE	0.563	0.130	0.073	0.012
TRICHLOROETHANE	0.021	0.002	0.000	0.000
VOC	0.397	15.011	5.959	1.000
XYLENE	0.849	0.056	0.048	0.008

# HUMAN HEALTH INHALATION TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	HH INHALATION		Inventory Value lb/FU	Factored Score	Normalized Factored Score
	TOXICITY	Equiv. Factor			
Total HH Inh. Tox. Factored Score				27.336	2.150
Normalizing Score				12.715	
ACETALDEHYDE	7.44	0.089	0.659	0.052	
ACETONE	0	0.008	0.000	0.000	
ACETONITRILE	0	0.000	0.000	0.000	
AMMONIA	5.7	0.000	0.000	0.000	
ALDEHYDES	NA	0.019	0.000	0.000	
ALUMINUM	15.6	0.003	0.046	0.004	
AROMATIC HYDROCARBONS (C8-C10)	NA	0.023	0.000	0.000	
BENZENE	NA	0.203	0.000	0.000	
BUTANE (n-)	17.5	0.059	1.033	0.081	
BUTANE (iso-)	NA	0.003	0.000	0.000	
BUTYL ACETATE (n-)	8.49	0.150	1.270	0.100	
BUTANOL	0.95	0.034	0.033	0.003	
BUTYL CELLOSOLVE	12.29	0.000	0.000	0.000	
BUTYLENE OXIDE, 1,2-	NA	0.000	0.000	0.000	
CADMIUM	2.25		0.000	0.000	
CARBON TETRACHLORIDE	7.06	0.003	0.020	0.002	
CHLORINE	22.05	0.577	12.715	1.000	
CHLOROFORM	2.57	0.001	0.003	0.000	
CO	4.47	1.386	6.195	0.487	
CO2	NA	300.337	0.000	0.000	
CUMENE	1.35	0.027	0.036	0.003	
CYCLOPARAFFINS, C-7	NA	0.012	0.000	0.000	
CYCLOPARAFFINS, C-8	NA	0.004	0.000	0.000	
DICHLORODIFLUOROMETHANE (CFC)	0	0.000	0.000	0.000	
ETHANE	NA	0.047	0.000	0.000	
ETHYL BENZENE	3.19	0.002	0.007	0.001	
ETHYLENE	0	0.003	0.000	0.000	
ETHYLENE CHLORIDE	0	0.003	0.000	0.000	
ETHYLENE DICHLORIDE	7.32	0.008	0.057	0.004	
FLUORINE	14.64	0.028	0.410	0.032	
FORMALDEHYDE	15.6	0.021	0.327	0.026	
HEAVY AROMATIC	NA	0.197	0.000	0.000	
HEPTANE (n-)	0	0.086	0.000	0.000	
HEXYL ACETATE	NA	0.056	0.000	0.000	
HEXAMETHYLENE DIISOCYANTE	10		0.000	0.000	
HEXANE (n-)	0	0.067	0.000	0.000	
HYDROCHLORIC ACID	14.82	0.001	0.020	0.002	
HYDROGEN CYANIDE	30	0.007	0.202	0.016	
ISOBUTYRALDEHYDE	1.86	0.328	0.610	0.048	
ISOPROPYL ALCOHOL	0	0.000	0.000	0.000	
LEAD	NA	0.001	0.000	0.000	
METHANE	NA	0.276	0.000	0.000	
METHANOL	0	0.000	0.000	0.000	

METHYL ETHYL KETONE	1.4	0.059	0.082	0.006
METHYL ISOAMYL KETONE	4	0.524	2.098	0.165
METHYL ISOBUTYL KETONE	2.33	0.023	0.054	0.004
METHYL PROPYL KETONE	NA	0.000	0.000	0.000
NAPHTHA, NM&P	NA	0.066	0.000	0.000
NAPHTHALENE	26.45		0.000	0.000
NOX	NA	6.099	0.000	0.000
NITRIC ACID	26.4	0.000	0.000	0.000
NITROETHANE	NA	0.000	0.000	0.000
NITROPROPANE	14.4	0.000	0.000	0.000
OCTANE (n-)	0	0.057	0.000	0.000
ORGANIC ACIDS	NA	0.025	0.000	0.000
PENTANE (n-)	13.34	0.042	0.554	0.044
PHENOL	22.33	0.022	0.483	0.038
PHOSGENE	12.5		0.000	0.000
PHOSPHORIC ACID	30		0.000	0.000
PM	NA	6.007	0.000	0.000
PM-10	NA	0.310	0.000	0.000
PROPANE	NA	0.074	0.000	0.000
PROPYL ACETATE	NA	0.000	0.000	0.000
TOLUENE	2.04	0.130	0.264	0.021
TRICHLOROETHANE (METHYL CHLO	5.6	0.002	0.013	0.001
VINYL CHLORIDE	18.52	0.001	0.026	0.002
VOC	NA	15.011	0.000	0.000
XYLENE	2.1	0.056	0.118	0.009

NA = Not Available

## TERRESTRIAL TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	TERRESTRIAL		Normalized Factored Score
	TOXICITY EQUIV. FACTOR	INVENTORY VALUE LB/FU	
Total Terr. Tox. Factored Score			4.084
Normalizing Score			3.799
ACETALDEHYDE	3.255	0.089	0.268
ACETONE	1.860	0.008	0.014
ACETONITRILE	0.610	0.000	0.000
ALUMINUM	0.000	0.001	0.000
AMMONIA	9.030	0.000	0.000
ARSENIC	31.730	0.000	0.001
BENZENE	0.000	0.204	0.000
BUTYL ACETATE (n-)	0.000	0.150	0.000
BUTYL ALCOHOL	6.180	0.034	0.212
BUTYL CELLOSOLVE	7.590	0.000	0.000
BUTYLENE OXIDE, 1,2-	1.610	0.000	0.000
CADMIUM	21.030	0.005	0.105
CARBON TETRACHLORIDE	1.710	0.003	0.005
CHLORINE	0.000	0.616	0.000
CHLOROFORM	6.160	0.001	0.008
CHROMIUM, TRIVALENT	19.290	0.001	0.011
COBALT COMPOUNDS	20.960		0.000
COPPER COMPOUNDS	12.000	0.000	0.000
CUMENE	2.710	0.027	0.073
DICHLORODIFLUOROMETHANE	1.330	0.000	0.000
DIETHYLAminETRIAMINE	5.270		0.000
ETHYL BENZENE	0.000	0.002	0.000
ETHYLENE	0.000	0.003	0.000
ETHYLENE DICHLORIDE	4.890		0.000
FGD SOLIDS	0.000	0.000	0.000
FLY ASH	0.000	0.000	0.000
FORMALDEHYDE	12.600	0.021	0.264
HEPTANE (n-)	9.500	0.086	0.814
HEXANE (n-)	0.000	0.067	0.000
HEXYL ACETATE	0.000	0.056	0.000
HEXAMETHYLENE DIISOCYANTE	2.640		0.000
HYDROCHLORIC ACID	5.740	0.001	0.008
HYDROGEN CYANIDE	30.000	0.007	0.202
IRON	0.000	0.000	0.000
ISOBUTYRALDEHYDE	1.860	0.328	0.610
ISOPROPYL ALCOHOL	0.950	0.000	0.000
KEROSENE	0.000	0.000	0.000
LEAD	5.750	0.003	0.015
METHYL ETHYL KETONE	1.860	0.059	0.109
METHYL ISOAMYL KETONE	2.050	0.524	1.075
METHYL ISOBUTYL KETONE	2.790	0.023	0.065

METHYL PROPYL KETONE	4.570	0.000	0.000	0.000
NAPHTHALENE	3.170		0.000	0.000
NITRIC ACID	10.200	0.000	0.000	0.000
NITROPROPANE, 2-	8.400		0.000	0.000
PHENOL	7.600	0.022	0.164	0.153
PHOSPHORIC ACID	5.400		0.000	0.000
PROPYL ACETATE	0.870	0.000	0.000	0.000
PLUTONIUM (FISSILE & NONFISSILE)	0.000	0.000	0.000	0.000
SLAG	0.000	0.000	0.000	0.000
SULFURIC ACID	3.600	0.000	0.000	0.000
TOLUENE	0.000	0.130	0.000	0.000
TRICHLOROETHANE (METHYL CHLOR	0.000	0.002	0.000	0.000
URANIUM (235, 236, 238)	NA	0.000	0.000	0.000
VINYL CHLORIDE	7.870	0.001	0.011	0.010
XYLENE	0.520	0.056	0.029	0.027
ZINC	0.000	0.000	0.000	0.000

NA = Not Available

## AQUATIC TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	AQUATIC TOXICITY Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total Aquatic Tox. Factored Score			1.128	1.280
Normalizing Score			0.881	
ACETONITRILE	0.000		0.000	0.000
AMMONIA	21.850		0.000	0.000
ALUMINUM	0.000	0.001	0.000	0.000
ARSENIC	18.750	0.000	0.001	0.001
BENZENE	14.070	0.001	0.010	0.011
BORON	0.000	0.015	0.000	0.000
BUTYL ALCOHOL	0.000	0.034	0.000	0.000
BUTYLENE OXIDE, 1,2-		NA	0.000	0.000
CADMIUM	36.250	0.005	0.180	0.204
CARBON TETRACHLORIDE	1.200		0.000	0.000
CHLORIDE	NA	11.375	0.000	0.000
CHLORINE	22.500	0.039	0.881	1.000
CHLOROFORM	9.750		0.000	0.000
CHROMIUM, TRIVALENT	16.630	0.001	0.009	0.010
COBALT COMPOUNDS	31.750		0.000	0.000
COPPER COMPOUNDS	30.000	0.000	0.001	0.001
DICHLORODIFLUOROMETHANE (CFC-1)	NA		0.000	0.000
HYDROCHLORIC ACID	13.860		0.000	0.000
IRON	25.000	0.000	0.000	0.000
LEAD	25.000	0.002	0.044	0.050
MERCURY	37.500	0.000	0.000	0.000
METHYL ISOAMYL KETONE	10.200		0.000	0.000
NAPHTHALENE	19.570		0.000	0.000
NITRIC ACID	15.600		0.000	0.000
NITROPROPANE, 2-	23.400		0.000	0.000
OIL & GREASE	NA	0.355	0.000	0.000
ORGANIC ACIDS	NA		0.000	0.000
PETROLEUM (CRUDE OIL)	NA	0.000	0.000	0.000
PHENOL	11.400	0.000	0.000	0.000
PHOSPHORIC ACID	11.400		0.000	0.000
SODIUM	NA	14.408	0.000	0.000
SULFIDE	NA	0.000	0.000	0.000
SULFURIC ACID	15.000	0.000	0.000	0.000
XYLENE	16.240		0.000	0.000
ZINC	20.300	0.000	0.001	0.001

NA = Not Available

**LAND USE IMPACT CALCULATIONS**

<b>CHEMICAL NAME</b>	<b>LAND USE Equiv. Factor</b>	<b>Inventory Value lb/FU</b>	<b>Factored Score</b>	<b>Normalized Factored Score</b>
Total Land Use Score			254.826	1.577
Normalizing Score			161.615	
BOTTOM ASH	2.000	0.000	0.000	0.000
FGD SOLIDS	2.000	0.000	0.000	0.000
FLY ASH	2.000	0.000	0.000	0.000
HAZARDOUS WASTE	2.000	80.808	161.615	1.000
PLUTONIUM (FISSILE & NONFISSILE)	NA	0.000	0.000	0.000
SLAG	2.000	0.000	0.000	0.000
SOLID WASTE	1.500	62.140	93.210	0.577
URANIUM (235, 236, 238)	NA	0.000	0.000	0.000

NA = Not Available

## **ALTERNATIVE PRIMER**

## LIFE CYCLE IMPACT VALUATION CALCULATIONS

CARCOPT	Scale	Issues ----->	AHP	Normalized Factor	Weighted Normalized Factor Score	Baseline Score
			Weighting Factor	Factored Score		
GLOBAL	ODP	0.17983	0.367			0.671
	GLBLWRM	0.11328	0.927			
	FSLFUELS	0.02855	1.121			
REGIONAL	ACIDDEP	0.06253	1.173			
	SMOG	0.13007	0.993			
	WTRUSE	0.01002				
LOCAL	TOXICITY	0.06155	1.612			
	HUMAN	0.02052	2.635			
	ENVTERR	0.02052	3.537			
	ENVAQ	0.02507	1.585			
	LANDUSE				0.040	
					0.226	0.266
					0.203	0.203
					0.066 0.105 0.032	0.073 0.129 0.000

**OZONE DEPLETION POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	ODP Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total ODP Score			0.001	0.367
Normalizing Factor			0.003	
CARBON TETRACHLORIDE	1.080	0.000	0.000	0.000
DICHLORODIFLUOROMETHANE	1.000	0.001	0.001	0.367
TRICHLOROETHANE (METHYL CHLOROFORM)	0.120	0.000	0.000	0.000

**GLOBAL WARMING POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	GWP	Inventory	Normalized	
	Equiv. Factor	Value lb/FU	Factored Score	Factored Score
Total GWP Score			278.555	0.927
Normalizing Score			300.337	
CARBON TETRACHLORIDE	1300	0.000	0.000	0.000
CO2	1	270.734	270.734	0.901
DICHLORODIFLUOROMETHANE	7100	0.001	7.821	0.026
TRICHLOROETHANE	100	0.000	0.000	0.000

**RESOURCE DEPLETION IMPACT CALCULATIONS**

<b>CHEMICAL NAME</b>	<b>RESOURCE DEPLETION</b>	<b>Inventory</b>	<b>Normalized</b>	
	<b>Equiv. Factor</b>	<b>Value lb/FU</b>	<b>Factored Score</b>	<b>Factored Score</b>
Total Resource Depetion Score			12,343.607	1.121
Normalizing Score			11,010.628	
BAUXITE	4	83.964	335.857	0.031
CHROME OXIDE	2	4.553	9.107	0.001
COAL	3	0.000	0.000	0.000
COBALT OXIDE	3	1.003	3.010	0.000
IRON ORE	3	1.341	4.023	0.000
LIMESTONE	1	4.653	4.653	0.000
MAGNESIUM ORE	1	2.249	2.249	0.000
NATURAL GAS	4	534.932	2,139.727	0.194
PETROLEUM (CRUDE OIL)	4	2,436.041	9,744.165	0.885
PHOSPHATE ROCK	3	0.000	0.000	0.000
SALT (SODIUM CHLORIDE)	1	43.469	43.469	0.004
SILICA	1	13.377	13.377	0.001
SODA ASH	1	2.624	2.624	0.000
THALLIUM	4		0.000	0.000
TITANIUM	3	13.782	41.345	0.004
URANIUM (235, 236, 238)	3	0.000	0.000	0.000
WATER INPUT	NA	40,210.766	0.000	0.000
ZINC	4	0.000	0.000	0.000

NA = Not Available

**ACIDIFICATION POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	Acid. Pot.	Inventory	Normalized	
	Equiv. Factor	Value lb/FU	Factored Score	Factored Score
Total Acid. Pot. Score			25.324	1.173
Normalizing Score			21.584	
AMMONIA	1.880	0.001	0.002	0.000
HYDROCHLORIC ACID	0.880	0.002	0.002	0.000
NOX	0.700	5.877	4.114	0.191
SOX	1.000	21.206	21.206	0.982

**PHOTOCHEMICAL OXIDANT POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	POCP Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total POCP Score			5.918	0.993
Normalizing Factor			5.959	
ACETALDEHYDE	0.527	0.040	0.021	0.004
ACETONE	0.178	0.007	0.001	0.000
ALDEHYDES	0.443	0.017	0.008	0.001
AROMATIC HYDROCARBONS (C8-C10)	0.761	0.038	0.029	0.005
BENZENE	0.189	0.201	0.038	0.006
BUTANE (n-)	0.410	0.052	0.021	0.004
BUTANE (iso-)	0.315	0.003	0.001	0.000
BUTYL ACETATE (n-)	0.323	0.000	0.000	0.000
BUTYL ALCOHOL	0.196	0.042	0.008	0.001
CHLOROFORM	0.021	0.000	0.000	0.000
ETHANE	0.082	0.042	0.003	0.001
ETHYL BENZENE	0.593	0.004	0.003	0.000
ETHYLENE	1.000	0.001	0.001	0.000
HEPTANE (n-)	0.529	0.076	0.040	0.007
HEXANE (n-)	0.421	0.059	0.025	0.004
METHANE	0.007	0.244	0.002	0.000
METHANOL	0.123	0.000	0.000	0.000
METHYL ETHYL KETONE	0.473	0.020	0.010	0.002
METHYL ISOAMYL KETONE	0.326	0.071	0.023	0.004
METHYL ISOBUTYL KETONE	0.326	0.000	0.000	0.000
METHYL PROPYL KETONE	0.326	0.000	0.000	0.000
OCTANE (n-)	0.493	0.051	0.025	0.004
PENTANE (n-)	0.408	0.037	0.015	0.003
PROPANE	0.420	0.066	0.028	0.005
PROPYL ACETATE	0.218	0.000	0.000	0.000
PROPYLENE	1.030	0.000	0.000	0.000
TOLUENE	0.563	0.114	0.064	0.011
TRICHLOROETHANE	0.021	0.000	0.000	0.000
VOC	0.397	13.894	5.516	0.926
XYLENE	0.849	0.043	0.036	0.006

# HUMAN HEALTH INHALATION TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	HH INHALATION		Factored Score	Normalized Factored Score
	TOXICITY Equiv. Factor	Inventory Value lb/FU		
Total HH Inh. Tox. Factored Score			20.499	1.612
Normalizing Score			12.715	
ACETALDEHYDE	7.44	0.040	0.301	0.024
ACETONE	0	0.007	0.000	0.000
ACETONITRILE	0	0.000	0.000	0.000
AMMONIA	5.7	0.001	0.005	0.000
ALDEHYDES	NA	0.017	0.000	0.000
ALUMINUM	15.6	0.000	0.006	0.000
AROMATIC HYDROCARBONS (C8-C10)	NA	0.038	0.000	0.000
BENZENE	NA	0.201	0.000	0.000
BUTANE (n-)	17.5	0.052	0.914	0.072
BUTANE (iso-)	NA	0.003	0.000	0.000
BUTYL ACETATE (n-)	8.49	0.000	0.000	0.000
BUTANOL	0.95	0.042	0.040	0.003
BUTYL CELLOSOLVE	12.29	0.000	0.000	0.000
BUTYLENE OXIDE, 1,2-	NA	0.000	0.000	0.000
CADMIUM	2.25		0.000	0.000
CARBON TETRACHLORIDE	7.06	0.000	0.000	0.000
CHLORINE	22.05	0.586	12.914	1.016
CHLOROFORM	2.57	0.000	0.000	0.000
CO	4.47	0.792	3.542	0.279
CO2	NA	270.734	0.000	0.000
CUMENE	1.35	0.023	0.030	0.002
CYCLOPARAFFINS, C-7	NA	0.011	0.000	0.000
CYCLOPARAFFINS, C-8	NA	0.004	0.000	0.000
DICHLORODIFLUORMETHANE (CFC-	0	0.001	0.000	0.000
ETHANE	NA	0.042	0.000	0.000
ETHYL BENZENE	3.19	0.004	0.014	0.001
ETHYLENE	0	0.001	0.000	0.000
ETHYLENE CHLORIDE	0	0.000	0.000	0.000
ETHYLENE DICHLORIDE	7.32	0.000	0.000	0.000
FLUORINE	14.64	0.000	0.000	0.000
FORMALDEHYDE	15.6	0.019	0.295	0.023
HEAVY AROMATIC	NA	0.197	0.000	0.000
HEPTANE (n-)	0	0.076	0.000	0.000
HEXYL ACETATE	NA	0.000	0.000	0.000
HEXAMETHYLENE DIISOCYANTE	10		0.000	0.000
HEXANE (n-)	0	0.059	0.000	0.000
HYDROCHLORIC ACID	14.82	0.002	0.029	0.002
HYDROGEN CYANIDE	30	0.007	0.204	0.016
ISOBUTYRALDEHYDE	1.86	0.328	0.610	0.048
ISOPROPYL ALCOHOL	0	0.000	0.000	0.000
LEAD	NA	0.000	0.000	0.000
METHANE	NA	0.244	0.000	0.000
METHANOL	0	0.000	0.000	0.000

METHYL ETHYL KETONE	1.4	0.020	0.029	0.002
METHYL ISOAMYL KETONE	4	0.071	0.284	0.022
METHYL ISOBUTYL KETONE	2.33	0.000	0.000	0.000
METHYL PROPYL KETONE	NA	0.000	0.000	0.000
NAPHTHA, NM&P	NA	0.000	0.000	0.000
NAPHTHALENE	26.45		0.000	0.000
NOX	NA	5.877	0.000	0.000
NITRIC ACID	26.4	0.000	0.000	0.000
NITROETHANE	NA	0.004	0.000	0.000
NITROPROPANE	14.4	0.001	0.009	0.001
OCTANE (n-)	0	0.051	0.000	0.000
ORGANIC ACIDS	NA	0.022	0.000	0.000
PENTANE (n-)	13.34	0.037	0.491	0.039
PHENOL	22.33	0.021	0.461	0.036
PHOSGENE	12.5		0.000	0.000
PHOSPHORIC ACID	30		0.000	0.000
PM	NA	5.958	0.000	0.000
PM-10	NA	0.310	0.000	0.000
PROPANE	NA	0.066	0.000	0.000
PROPYL ACETATE	NA	0.000	0.000	0.000
TOLUENE	2.04	0.114	0.232	0.018
TRICHLOROETHANE (METHYL CHLO	5.6	0.000	0.000	0.000
VINYL CHLORIDE	18.52	0.000	0.000	0.000
VOC	NA	13.894	0.000	0.000
XYLENE	2.1	0.043	0.090	0.007

NA = Not Available

**TERRESTRIAL TOXICITY IMPACT CALCULATIONS**

<b>CHEMICAL NAME</b>	<b>TERRESTRIAL</b>		<b>Inventory Value lb/FU</b>	<b>Factored Score</b>	<b>Normalized Factored Score</b>
	<b>TOXICITY Equiv. Factor</b>	<b>Inventory Value lb/FU</b>			
Total Terr. Tox. Factored Score				2.832	2.635
Normalizing Score				1.075	
ACETALDEHYDE	3.255	0.040	0.132	0.123	
ACETONE	1.860	0.007	0.014	0.013	
ACETONITRILE	0.610	0.005	0.003	0.003	
ALUMINUM	0.000	0.001	0.000	0.000	
AMMONIA	9.030	0.001	0.008	0.007	
ARSENIC	31.730	0.000	0.001	0.001	
BENZENE	0.000	0.202	0.000	0.000	
BUTYL ACETATE (n-)	0.000	0.000	0.000	0.000	
BUTYL ALCOHOL	6.180	0.042	0.258	0.240	
BUTYL CELLOSOLVE	7.590	0.000	0.000	0.000	
BUTYLENE OXIDE, 1,2-	1.610	0.000	0.000	0.000	
CADMIUM	21.030	0.008	0.167	0.156	
CARBON TETRACHLORIDE	1.710	0.000	0.000	0.000	
CHLORINE	0.000	0.707	0.000	0.000	
CHLOROFORM	6.160	0.000	0.000	0.000	
CHROMIUM, TRIVALENT	19.290	0.001	0.017	0.016	
COBALT COMPOUNDS	20.960		0.000	0.000	
COPPER COMPOUNDS	12.000	0.000	0.001	0.001	
CUMENE	2.710	0.023	0.061	0.057	
DICHLORODIFLUORMETHANE	1.330	0.001	0.001	0.001	
DIETHYLMINETRIAMINE	5.270		0.000	0.000	
ETHYL BENZENE	0.000	0.004	0.000	0.000	
ETHYLENE	0.000	0.001	0.000	0.000	
ETHYLENE DICHLORIDE	4.890		0.000	0.000	
FGD SOLIDS	0.000	0.000	0.000	0.000	
FLY ASH	0.000	0.000	0.000	0.000	
FORMALDEHYDE	12.600	0.019	0.238	0.221	
HEPTANE (n-)	9.500	0.076	0.721	0.670	
HEXANE (n-)	0.000	0.059	0.000	0.000	
HEXYL ACETATE	0.000	0.000	0.000	0.000	
HEXAMETHYLENE DIISOCYANTE	2.640		0.000	0.000	
HYDROCHLORIC ACID	5.740	0.002	0.011	0.010	
HYDROGEN CYANIDE	30.000	0.007	0.204	0.189	
IRON	0.000	0.000	0.000	0.000	
ISOBUTYRALDEHYDE	1.860	0.328	0.610	0.567	
ISOPROPYL ALCOHOL	0.950	0.000	0.000	0.000	
KEROSENE	0.000	0.000	0.000	0.000	
LEAD	5.750	0.003	0.017	0.016	
METHYL ETHYL KETONE	1.860	0.020	0.038	0.035	
METHYL ISOAMYL KETONE	2.050	0.071	0.146	0.135	
METHYL ISOBUTYL KETONE	2.790	0.000	0.000	0.000	

METHYL PROPYL KETONE	4.570	0.000	0.000	0.000
NAPHTHALENE	3.170	0.000	0.000	0.000
NITRIC ACID	10.200	0.001	0.007	0.006
NITROPROPANE, 2-	8.400	0.000	0.000	0.000
PHENOL	7.600	0.021	0.157	0.146
PHOSPHORIC ACID	5.400	0.000	0.000	0.000
PROPYL ACETATE	0.870	0.000	0.000	0.000
PLUTONIUM (FISSILE & NONFISSILE)	0.000	0.000	0.000	0.000
SLAG	0.000	0.000	0.000	0.000
SULFURIC ACID	3.600	0.000	0.000	0.000
TOLUENE	0.000	0.114	0.000	0.000
TRICHLOROETHANE (METHYL CHLOR	0.000	0.000	0.000	0.000
URANIUM (235, 236, 238)	NA	0.000	0.000	0.000
VINYL CHLORIDE	7.870	0.000	0.000	0.000
XYLENE	0.520	0.043	0.022	0.021
ZINC	0.000	0.000	0.000	0.000

NA = Not Available

## AQUATIC TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	AQUATIC TOXICITY	Inventory	Normalized	
	Equiv. Factor	Value lb/FU	Factored Score	Factored Score
Total Aquatic Tox. Factored Score			3.116	3.537
Normalizing Score			0.881	
ACETONITRILE	0.000		0.000	0.000
AMMONIA	21.850		0.000	0.000
ALUMINUM	0.000	0.001	0.000	0.000
ARSENIC	18.750	0.000	0.000	0.001
BENZENE	14.070	0.001	0.009	0.010
BORON	0.000	0.013	0.000	0.000
BUTYL ALCOHOL	0.000	0.042	0.000	0.000
BUTYLENE OXIDE, 1,2-	NA		0.000	0.000
CADMIUM	36.250	0.008	0.289	0.328
CARBON TETRACHLORIDE	1.200		0.000	0.000
CHLORIDE	NA	10.067	0.000	0.000
CHLORINE	22.500	0.121	2.727	3.095
CHLOROFORM	9.750		0.000	0.000
CHROMIUM, TRIVALENT	16.630	0.001	0.015	0.017
COBALT COMPOUNDS	31.750		0.000	0.000
COPPER COMPOUNDS	30.000	0.000	0.002	0.002
DICHLORODIFLUOROMETHANE (CFC-1)	NA		0.000	0.000
HYDROCHLORIC ACID	13.860		0.000	0.000
IRON	25.000	0.000	0.000	0.000
LEAD	25.000	0.003	0.073	0.082
MERCURY	37.500	0.000	0.000	0.000
METHYL ISOAMYL KETONE	10.200		0.000	0.000
NAPHTHALENE	19.570		0.000	0.000
NITRIC ACID	15.600		0.000	0.000
NITROPROPANE, 2-	23.400		0.000	0.000
OIL & GREASE	NA	0.314	0.000	0.000
ORGANIC ACIDS	NA		0.000	0.000
PETROLEUM (CRUDE OIL)	NA	0.000	0.000	0.000
PHENOL	11.400	0.000	0.000	0.000
PHOSPHORIC ACID	11.400		0.000	0.000
SODIUM	NA	12.751	0.000	0.000
SULFIDE	NA	0.000	0.000	0.000
SULFURIC ACID	15.000	0.000	0.000	0.000
XYLENE	16.240		0.000	0.000
ZINC	20.300	0.000	0.001	0.002

NA = Not Available

## LAND USE IMPACT CALCULATIONS

<u>CHEMICAL NAME</u>	<u>LAND USE Equiv. Factor</u>	<u>Inventory Value lb/FU</u>	<u>Factored Score</u>	<u>Normalized Factored Score</u>
Total Land Use Score			251.882	1.585
Normalizing Score			161.615	
BOTTOM ASH	2.000	0.000	0.000	0.000
FGD SOLIDS	2.000	0.000	0.000	0.000
FLY ASH	2.000	0.000	0.000	0.000
HAZARDOUS WASTE	2.000	79.465	158.930	1.000
PLUTONIUM (FISSILE & NONFISSILE)	NA	0.000	0.000	0.000
SLAG	2.000	0.000	0.000	0.000
SOLID WASTE	1.500	61.968	92.951	0.585
URANIUM (235, 236, 238)	NA	0.000	0.000	0.000

NA = Not Available

## **ALTERNATIVE GUN**

## LIFE CYCLE IMPACT VALUATION CALCULATIONS

CARCOPT	Scale	Issues ----->	AHP Weighting Factor	Normalized Factored Score	Weighted Normalized Factored Score	Baseline Score
						► 0.630
GLOBAL	ODP	0.17983	0.799	0.144	► 0.254	
	GLBLWRM	0.11328	0.739	0.084		
	FSLFUELS	0.02855	0.929	0.027		
REGIONAL	ACIDDEP	0.06253	1.116	0.070	► 0.174	
	SMOG	0.13007	0.800	0.104		
	WTRUSE	0.01002		0.000		
LOCAL	TOXICITY			0.202		
	HUMAN	0.06155	1.510	0.093		
	ENVERR	0.02052	2.565	0.053		
	ENVAQ	0.02052	0.925	0.019		
	LANDUSE	0.02507	1.493		0.037	

**OZONE DEPLETION POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	ODP Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total ODP Score			0.002	0.799
Normalizing Factor			0.003	
CARBON TETRACHLORIDE	1.080	0.002	0.002	0.732
DICHLORODIFLUOROMETHANE	1.000	0.000	0.000	0.000
TRICHLOROETHANE (METHYL CHLOROFORM)	0.120	0.002	0.000	0.066

**GLOBAL WARMING POTENTIAL IMPACT CALCULATIONS**

<b>CHEMICAL NAME</b>	<b>GWP Equiv. Factor</b>	<b>Inventory Value lb/FU</b>	<b>Factored Score</b>	<b>Normalized Factored Score</b>
Total GWP Score			221.802	0.739
Normalizing Score			300.337	
CARBON TETRACHLORIDE	1300	0.002	2.645	0.009
CO2	1	218.992	218.992	0.729
DICHLORODIFLUOROMETHANE	7100	0.000	0.000	0.000
TRICHLOROETHANE	100	0.002	0.165	0.001

## RESOURCE DEPLETION IMPACT CALCULATIONS

CHEMICAL NAME	RESOURCE DEPLETION	Inventory		Normalized
	Equiv. Factor	Value lb/FU	Factored Score	Factored Score
Total Resource Depetion Score			10,233.632	0.929
Normalizing Score			11,010.628	
BAUXITE	4	83.964	335.857	0.031
CHROME OXIDE	2	3.288	6.575	0.001
COAL	3	0.211	0.632	0.000
COBALT OXIDE	3	0.724	2.173	0.000
IRON ORE	3	0.925	2.776	0.000
LIMESTONE	1	4.653	4.653	0.000
MAGNESIUM ORE	1	1.624	1.624	0.000
NATURAL GAS	4	439.669	1,758.676	0.160
PETROLEUM (CRUDE OIL)	4	2,007.554	8,030.216	0.729
PHOSPHATE ROCK	3	1.511	4.532	0.000
SALT (SODIUM CHLORIDE)	1	31.106	31.106	0.003
SILICA	1	9.861	9.861	0.001
SODA ASH	1	2.624	2.624	0.000
THALLIUM	4		0.000	0.000
TITANIUM	3	6.073	18.220	0.002
URANIUM (235, 236, 238)	3	0.000	0.000	0.000
WATER INPUT	NA	31,785.094	0.000	0.000
ZINC	4	6.027	24.108	0.002

NA = Not Available

**ACIDIFICATION POTENTIAL IMPACT CALCULATIONS**

<b>CHEMICAL NAME</b>	<b>Acid. Pot.</b>	<b>Inventory</b>	<b>Normalized</b>	
	<b>Equiv. Factor</b>	<b>Value lb/FU</b>	<b>Factored Score</b>	<b>Factored Score</b>
Total Acid. Pot. Score			24.080	1.116
Normalizing Score			21.584	
AMMONIA	1.880	0.000	0.000	0.000
HYDROCHLORIC ACID	0.880	0.001	0.001	0.000
NOX	0.700	4.418	3.093	0.143
SOX	1.000	20.986	20.986	0.972

**PHOTOCHEMICAL OXIDANT POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	POCP	Inventory	Normalized	
	Equiv. Factor	Value lb/FU	Factored Score	Factored Score
Total POCP Score			4.768	0.800
Normalizing Factor			5.959	
ACETALDEHYDE	0.527	0.066	0.035	0.006
ACETONE	0.178	0.006	0.001	0.000
ALDEHYDES	0.443	0.014	0.006	0.001
AROMATIC HYDROCARBONS (C8-C10)	0.761	0.012	0.009	0.002
BENZENE	0.189	0.153	0.029	0.005
BUTANE (n-)	0.410	0.043	0.018	0.003
BUTANE (iso-)	0.315	0.002	0.001	0.000
BUTYL ACETATE (n-)	0.323	0.079	0.026	0.004
BUTYL ALCOHOL	0.196	0.018	0.003	0.001
CHLOROFORM	0.021	0.001	0.000	0.000
ETHANE	0.082	0.035	0.003	0.000
ETHYL BENZENE	0.593	0.002	0.001	0.000
ETHYLENE	1.000	0.002	0.002	0.000
HEPTANE (n-)	0.529	0.063	0.033	0.006
HEXANE (n-)	0.421	0.049	0.020	0.003
METHANE	0.007	0.201	0.001	0.000
METHANOL	0.123	0.000	0.000	0.000
METHYL ETHYL KETONE	0.473	0.040	0.019	0.003
METHYL ISOAMYL KETONE	0.326	0.288	0.094	0.016
METHYL ISOBUTYL KETONE	0.326	0.014	0.005	0.001
METHYL PROPYL KETONE	0.326	0.000	0.000	0.000
OCTANE (n-)	0.493	0.042	0.021	0.003
PENTANE (n-)	0.408	0.030	0.012	0.002
PROPANE	0.420	0.054	0.023	0.004
PROPYL ACETATE	0.218	0.000	0.000	0.000
PROPYLENE	1.030	0.000	0.000	0.000
TOLUENE	0.563	0.098	0.055	0.009
TRICHLOROETHANE	0.021	0.002	0.000	0.000
VOC	0.397	10.892	4.324	0.726
XYLENE	0.849	0.032	0.027	0.005

# HUMAN HEALTH INHALATION TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	HH INHALATION		Factored Score	Normalized Factored Score
	TOXICITY EQUIV. FACTOR	INVENTORY VALUE LB/FU		
Total HH inh. Tox. Factored Score			19.203	1.510
Normalizing Score			12.715	
ACETALDEHYDE	7.44	0.066	0.493	0.039
ACETONE	0	0.006	0.000	0.000
ACETONITRILE	0	0.000	0.000	0.000
AMMONIA	5.7	0.000	0.000	0.000
ALDEHYDES	NA	0.014	0.000	0.000
ALUMINUM	15.6	0.002	0.033	0.003
AROMATIC HYDROCARBONS (C8-C10)	NA	0.012	0.000	0.000
BENZENE	NA	0.153	0.000	0.000
BUTANE (n-)	17.5	0.043	0.753	0.059
BUTANE (iso-)	NA	0.002	0.000	0.000
BUTYL ACETATE (n-)	8.49	0.079	0.674	0.053
BUTANOL	0.95	0.018	0.017	0.001
BUTYL CELLOSOLVE	12.29	0.000	0.000	0.000
BUTYLENE OXIDE, 1,2-	NA	0.000	0.000	0.000
CADMIUM	2.25		0.000	0.000
CARBON TETRACHLORIDE	7.06	0.002	0.014	0.001
CHLORINE	22.05	0.416	9.180	0.722
CHLOROFORM	2.57	0.001	0.002	0.000
CO	4.47	1.007	4.502	0.354
CO2	NA	218.992	0.000	0.000
CUMENE	1.35	0.019	0.026	0.002
CYCLOPARAFFINS, C-7	NA	0.009	0.000	0.000
CYCLOPARAFFINS, C-8	NA	0.003	0.000	0.000
DICHLORODIFLUOROMETHANE (CFC)	0	0.000	0.000	0.000
ETHANE	NA	0.035	0.000	0.000
ETHYL BENZENE	3.19	0.002	0.005	0.000
ETHYLENE	0	0.002	0.000	0.000
ETHYLENE CHLORIDE	0	0.002	0.000	0.000
ETHYLENE DICHLORIDE	7.32	0.006	0.041	0.003
FLUORINE	14.64	0.020	0.296	0.023
FORMALDEHYDE	15.6	0.015	0.238	0.019
HEAVY AROMATIC	NA	0.142	0.000	0.000
HEPTANE (n-)	0	0.063	0.000	0.000
HEXYL ACETATE	NA	0.035	0.000	0.000
HEXAMETHYLENE DIISOCYANTE	10		0.000	0.000
HEXANE (n-)	0	0.049	0.000	0.000
HYDROCHLORIC ACID	14.82	0.001	0.014	0.001
HYDROGEN CYANIDE	30	0.005	0.146	0.011
ISOBUTYRALDEHYDE	1.86	0.257	0.478	0.038
ISOPROPYL ALCOHOL	0	0.000	0.000	0.000
LEAD	NA	0.001	0.000	0.000
METHANE	NA	0.201	0.000	0.000
METHANOL	0	0.000	0.000	0.000

METHYL ETHYL KETONE	1.4	0.040	0.055	0.004
METHYL ISOAMYL KETONE	4	0.288	1.151	0.090
METHYL ISOBUTYL KETONE	2.33	0.014	0.033	0.003
METHYL PROPYL KETONE	NA	0.000	0.000	0.000
NAPHTHA, NM&P	NA	0.034	0.000	0.000
NAPHTHALENE	26.45		0.000	0.000
NOX	NA	4.418	0.000	0.000
NITRIC ACID	26.4	0.000	0.000	0.000
NITROETHANE	NA	0.000	0.000	0.000
NITROPROPANE	14.4	0.000	0.000	0.000
OCTANE (n-)	0	0.042	0.000	0.000
ORGANIC ACIDS	NA	0.018	0.000	0.000
PENTANE (n-)	13.34	0.030	0.404	0.032
PHENOL	22.33	0.016	0.349	0.027
PHOSGENE	12.5		0.000	0.000
PHOSPHORIC ACID	30		0.000	0.000
PM	NA	4.425	0.000	0.000
PM-10	NA	0.292	0.000	0.000
PROPANE	NA	0.054	0.000	0.000
PROPYL ACETATE	NA	0.000	0.000	0.000
TOLUENE	2.04	0.098	0.201	0.016
TRICHLOROETHANE (METHYL CHLO	5.6	0.002	0.009	0.001
VINYL CHLORIDE	18.52	0.001	0.019	0.002
VOC	NA	10.892	0.000	0.000
XYLENE	2.1	0.032	0.067	0.005

NA = Not Available

**TERRESTRIAL TOXICITY IMPACT CALCULATIONS**

<b>CHEMICAL NAME</b>	<b>TERRESTRIAL</b>		<b>Normalized Factored Score</b>
	<b>TOXICITY EQUIV. FACTOR</b>	<b>Inventory Value lb/FU</b>	
Total Terr. Tox. Factored Score			2.757
Normalizing Score			1.075
ACETALDEHYDE	3.255	0.066	0.216
ACETONE	1.860	0.006	0.011
ACETONITRILE	0.610	0.000	0.000
ALUMINUM	0.000	0.000	0.000
AMMONIA	9.030	0.000	0.000
ARSENIC	31.730	0.000	0.001
BENZENE	0.000	0.154	0.000
BUTYL ACETATE (n-)	0.000	0.079	0.000
BUTYL ALCOHOL	6.180	0.018	0.110
BUTYL CELLOSOLVE	7.590	0.000	0.000
BUTYLENE OXIDE, 1,2-	1.610	0.000	0.000
CADMIUM	21.030	0.004	0.076
CARBON TETRACHLORIDE	1.710	0.002	0.003
CHLORINE	0.000	0.445	0.000
CHLOROFORM	6.160	0.001	0.006
CHROMIUM, TRIVALENT	19.290	0.000	0.008
COBALT COMPOUNDS	20.960		0.000
COPPER COMPOUNDS	12.000	0.000	0.000
CUMENE	2.710	0.019	0.052
DICHLORODIFLUOROMETHANE	1.330	0.000	0.000
DIETHYLMINETRIAMINE	5.270		0.000
ETHYL BENZENE	0.000	0.002	0.000
ETHYLENE	0.000	0.002	0.000
ETHYLENE DICHLORIDE	4.890		0.000
FGD SOLIDS	0.000	0.000	0.000
FLY ASH	0.000	0.000	0.000
FORMALDEHYDE	12.600	0.015	0.192
HEPTANE (n-)	9.500	0.063	0.594
HEXANE (n-)	0.000	0.049	0.000
HEXYL ACETATE	0.000	0.035	0.000
HEXAMETHYLENE DIISOCYANTE	2.640		0.000
HYDROCHLORIC ACID	5.740	0.001	0.005
HYDROGEN CYANIDE	30.000	0.005	0.146
IRON	0.000	0.000	0.000
ISOBUTYRALDEHYDE	1.860	0.257	0.478
ISOPROPYL ALCOHOL	0.950	0.000	0.000
KEROSENE	0.000	0.000	0.000
LEAD	5.750	0.002	0.011
METHYL ETHYL KETONE	1.860	0.040	0.074
METHYL ISOAMYL KETONE	2.050	0.288	0.590
METHYL ISOBUTYL KETONE	2.790	0.014	0.040

METHYL PROPYL KETONE	4.570	0.000	0.000	0.000
NAPHTHALENE	3.170		0.000	0.000
NITRIC ACID	10.200	0.000	0.000	0.000
NITROPROPANE, 2-	8.400		0.000	0.000
PHENOL	7.600	0.016	0.119	0.110
PHOSPHORIC ACID	5.400		0.000	0.000
PROPYL ACETATE	0.870	0.000	0.000	0.000
PLUTONIUM (FISSILE & NONFISSILE)	0.000	0.000	0.000	0.000
SLAG	0.000	0.000	0.000	0.000
SULFURIC ACID	3.600	0.000	0.000	0.000
TOLUENE	0.000	0.098	0.000	0.000
TRICHLOROETHANE (METHYL CHLOR	0.000	0.002	0.000	0.000
URANIUM (235, 236, 238)	NA	0.000	0.000	0.000
VINYL CHLORIDE	7.870	0.001	0.008	0.008
XYLENE	0.520	0.032	0.017	0.016
ZINC	0.000	0.000	0.000	0.000

NA = Not Available

## AQUATIC TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	AQUATIC TOXICITY	Inventory	Factored Score	Normalized Factored Score
	Equiv. Factor	Value lb/FU		
Total Aquatic Tox. Factored Score			0.815	0.925
Normalizing Score			0.881	
ACETONITRILE	0.000		0.000	0.000
AMMONIA	21.850		0.000	0.000
ALUMINUM	0.000	0.000	0.000	0.000
ARSENIC	18.750	0.000	0.000	0.000
BENZENE	14.070	0.001	0.007	0.008
BORON	0.000	0.011	0.000	0.000
BUTYL ALCOHOL	0.000	0.018	0.000	0.000
BUTYLENE OXIDE, 1,2-	NA		0.000	0.000
CADMIUM	36.250	0.004	0.130	0.148
CARBON TETRACHLORIDE	1.200		0.000	0.000
CHLORIDE	NA	8.296	0.000	0.000
CHLORINE	22.500	0.028	0.636	0.722
CHLOROFORM	9.750		0.000	0.000
CHROMIUM, TRIVALENT	16.630	0.000	0.007	0.008
COBALT COMPOUNDS	31.750		0.000	0.000
COPPER COMPOUNDS	30.000	0.000	0.001	0.001
DICHLORODIFLUOROMETHANE (CFC-1)	NA		0.000	0.000
HYDROCHLORIC ACID	13.860		0.000	0.000
IRON	25.000	0.000	0.000	0.000
LEAD	25.000	0.001	0.032	0.036
MERCURY	37.500	0.000	0.000	0.000
METHYL ISOAMYL KETONE	10.200		0.000	0.000
NAPHTHALENE	19.570		0.000	0.000
NITRIC ACID	15.600		0.000	0.000
NITROPROPANE, 2-	23.400		0.000	0.000
OIL & GREASE	NA	0.259	0.000	0.000
ORGANIC ACIDS	NA		0.000	0.000
PETROLEUM (CRUDE OIL)	NA	0.000	0.000	0.000
PHENOL	11.400	0.000	0.000	0.000
PHOSPHORIC ACID	11.400		0.000	0.000
SODIUM	NA	10.508	0.000	0.000
SULFIDE	NA	0.000	0.000	0.000
SULFURIC ACID	15.000	0.000	0.000	0.000
XYLENE	16.240		0.000	0.000
ZINC	20.300	0.000	0.001	0.001

NA = Not Available

## LAND USE IMPACT CALCULATIONS

<b>CHEMICAL NAME</b>	<b>LAND USE EQUIV. FACTOR</b>	<b>INVENTORY VALUE LB/FU</b>	<b>FACTORED SCORE</b>	<b>NORMALIZED FACTORED SCORE</b>
Total Land Use Score			239.296	1.493
Normalizing Score			161.615	
BOTTOM ASH	2.000	0.000	0 000	0.000
FGD SOLIDS	2.000	0.000	0.000	0.000
FLY ASH	2.000	0.000	0.000	0.000
HAZARDOUS WASTE	2.000	80.163	160.327	1.000
PLUTONIUM (FISSILE & NONFISSILE)	NA	0.000	0.000	0.000
SLAG	2.000	0.000	0.000	0.000
SOLID WASTE	1.500	52.646	78.970	0.493
URANIUM (235, 236, 238)	NA	0.000	0.000	0.000

NA = Not Available

## **ALTERNATIVE PRIMER AND GUN**

## LIFE CYCLE IMPACT VALUATION CALCULATIONS

CARCOPT	Scale	Issues ----->	AHP	Normalized Factor	Weighted Normalized Factored Score	Baseline Score
			Weighting Factor			
GLOBAL	ODP	0.17983	0.265			0.511
	GLBLWRM	0.11328	0.677			
	FSLFUELS	0.02855	0.827			
REGIONAL	ACIDDEP	0.06253	1.098			
	SMOG	0.13007	0.721			
	WTRUSE	0.01002				
LOCAL	TOXICITY					
	HUMAN	0.06155	1.172			
	ENVTERR	0.02052	1.906			
LANDUSE	ENVAQ	0.02052	2.554			
	LANDUSE	0.02507	1.497			
				0.048 0.077 0.024	0.148 0.162 0.201	0.164
				0.069 0.094 0.000		
				0.038		

**OZONE DEPLETION POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	ODP Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total ODP Score			0.001	0.265
Normalizing Factor			0.003	
CARBON TETRACHLORIDE	1.080	0.000	0.000	0.000
DICHLORODIFLUOROMETHANE	1.000	0.001	0.001	0.265
TRICHLOROETHANE (METHYL CHLOROFORM)	0.120	0.000	0.000	0.000

**GLOBAL WARMING POTENTIAL IMPACT CALCULATIONS**

<b>CHEMICAL NAME</b>	<b>GWP Equiv. Factor</b>	<b>Inventory Value lb/FU</b>	<b>Factored Score</b>	<b>Normalized Factored Score</b>
Total GWP Score			203.264	0.677
Normalizing Score			300.337	
CARBON TETRACHLORIDE	1300	0.000	0.000	0.000
CO2	1	197.618	197.618	0.658
DICHLORODIFLUOROMETHANE	7100	0.001	5.646	0.019
TRICHLOROETHANE	100	0.000	0.000	0.000

## RESOURCE DEPLETION IMPACT CALCULATIONS

CHEMICAL NAME	RESOURCE DEPLETION	Inventory	Normalized			
			Equiv. Factor	Value lb/FU	Factored Score	Factored Score
Total Resource Depetion Score					9,105.511	0.827
Normalizing Score					11,010.628	
BAUXITE	4	83.964		335.857	0.031	
CHROME OXIDE	2	3.288		6.575	0.001	
COAL	3	0.000		0.000	0.000	
COBALT OXIDE	3	0.724		2.173	0.000	
IRON ORE	3	0.968		2.905	0.000	
LIMESTONE	1	4.653		4.653	0.000	
MAGNESIUM ORE	1	1.624		1.624	0.000	
NATURAL GAS	4	390.599		1,562.395	0.142	
PETROLEUM (CRUDE OIL)	4	1,778.953		7,115.812	0.646	
PHOSPHATE ROCK	3	0.000		0.000	0.000	
SALT (SODIUM CHLORIDE)	1	31.384		31.384	0.003	
SILICA	1	9.658		9.658	0.001	
SODA ASH	1	2.624		2.624	0.000	
THALLIUM	4			0.000	0.000	
TITANIUM	3	9.950		29.851	0.003	
URANIUM (235, 236, 238)	3	0.000		0.000	0.000	
WATER INPUT	NA	29,269.170		0.000	0.000	
ZINC	4	0.000		0.000	0.000	

NA = Not Available

**ACIDIFICATION POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	Acid. Pot.	Inventory	Normalized	
	Equiv. Factor	Value lb/FU	Factored Score	Factored Score
Total Acid. Pot. Score			23.696	1.098
Normalizing Score			21.584	
AMMONIA	1.880	0.001	0.001	0.000
HYDROCHLORIC ACID	0.880	0.001	0.001	0.000
NOX	0.700	4.258	2.981	0.138
SOX	1.000	20.713	20.713	0.960

**PHOTOCHEMICAL OXIDANT POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	POCP Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total POCP Score			4.294	0.721
Normalizing Factor			5.959	
ACETALDEHYDE	0.527	0.031	0.017	0.003
ACETONE	0.178	0.005	0.001	0.000
ALDEHYDES	0.443	0.012	0.006	0.001
AROMATIC HYDROCARBONS (C8-C10)	0.761	0.020	0.015	0.003
BENZENE	0.189	0.151	0.029	0.005
BUTANE (n-)	0.410	0.038	0.016	0.003
BUTANE (iso-)	0.315	0.002	0.001	0.000
BUTYL ACETATE (n-)	0.323	0.000	0.000	0.000
BUTYL ALCOHOL	0.196	0.022	0.004	0.001
CHLOROFORM	0.021	0.000	0.000	0.000
ETHANE	0.082	0.031	0.003	0.000
ETHYL BENZENE	0.593	0.003	0.002	0.000
ETHYLENE	1.000	0.000	0.000	0.000
HEPTANE (n-)	0.529	0.055	0.029	0.005
HEXANE (n-)	0.421	0.043	0.018	0.003
METHANE	0.007	0.178	0.001	0.000
METHANOL	0.123	0.000	0.000	0.000
METHYL ETHYL KETONE	0.473	0.016	0.008	0.001
METHYL ISOAMYL KETONE	0.326	0.051	0.017	0.003
METHYL ISOBUTYL KETONE	0.326	0.000	0.000	0.000
METHYL PROPYL KETONE	0.326	0.000	0.000	0.000
OCTANE (n-)	0.493	0.037	0.018	0.003
PENTANE (n-)	0.408	0.027	0.011	0.002
PROPANE	0.420	0.048	0.020	0.003
PROPYL ACETATE	0.218	0.000	0.000	0.000
PROPYLENE	1.030	0.000	0.000	0.000
TOLUENE	0.563	0.088	0.050	0.008
TRICHLOROETHANE	0.021	0.000	0.000	0.000
VOC	0.397	10.085	4.004	0.672
XYLENE	0.849	0.031	0.026	0.004

# HUMAN HEALTH INHALATION TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	HH INHALATION		Inventory Value lb/FU	Factored Score	Normalized Factored Score
	TOXICITY	Equiv. Factor			
Total HH Inh. Tox. Factored Score				14.900	1.172
Normalizing Score				12.715	
ACETALDEHYDE	7.44	0.031	0.234	0.018	
ACETONE	0	0.005	0.000	0.000	
ACETONITRILE	0	0.000	0.000	0.000	
AMMONIA	5.7	0.001	0.004	0.000	
ALDEHYDES	NA	0.012	0.000	0.000	
ALUMINUM	15.6	0.000	0.000	0.000	
AROMATIC HYDROCARBONS (C8-C10)	NA	0.020	0.000	0.000	
BENZENE	NA	0.151	0.000	0.000	
BUTANE (n-)	17.5	0.038	0.667	0.052	
BUTANE (iso-)	NA	0.002	0.000	0.000	
BUTYL ACETATE (n-)	8.49	0.000	0.000	0.000	
BUTANOL	0.95	0.022	0.021	0.002	
BUTYL CELLOSOLVE	12.29	0.000	0.000	0.000	
BUTYLENE OXIDE, 1,2-	NA	0.000	0.000	0.000	
CADMIUM	2.25		0.000	0.000	
CARBON TETRACHLORIDE	7.06	0.000	0.000	0.000	
CHLORINE	22.05	0.423	9.324	0.733	
CHLOROFORM	2.57	0.000	0.000	0.000	
CO	4.47	0.579	2.586	0.203	
CO2	NA	197.618	0.000	0.000	
CUMENE	1.35	0.016	0.022	0.002	
CYCLOPARAFFINS, C-7	NA	0.008	0.000	0.000	
CYCLOPARAFFINS, C-8	NA	0.003	0.000	0.000	
DICHLORODIFLUORMETHANE (CFC-	0	0.001	0.000	0.000	
ETHANE	NA	0.031	0.000	0.000	
ETHYL BENZENE	3.19	0.003	0.010	0.001	
ETHYLENE	0	0.000	0.000	0.000	
ETHYLENE CHLORIDE	0	0.000	0.000	0.000	
ETHYLENE DICHLORIDE	7.32	0.000	0.000	0.000	
FLUORINE	14.64	0.000	0.000	0.000	
FORMALDEHYDE	15.6	0.014	0.215	0.017	
HEAVY AROMATIC	NA	0.142	0.000	0.000	
HEPTANE (n-)	0	0.055	0.000	0.000	
HEXYL ACETATE	NA	0.000	0.000	0.000	
HEXAMETHYLENE DIISOCYANTE	10		0.000	0.000	
HEXANE (n-)	0	0.043	0.000	0.000	
HYDROCHLORIC ACID	14.82	0.001	0.021	0.002	
HYDROGEN CYANIDE	30	0.005	0.147	0.012	
ISOBUTYRALDEHYDE	1.86	0.257	0.478	0.038	
ISOPROPYL ALCOHOL	0	0.000	0.000	0.000	
LEAD	NA	0.000	0.000	0.000	
METHANE	NA	0.178	0.000	0.000	
METHANOL	0	0.000	0.000	0.000	

METHYL ETHYL KETONE	1.4	0.016	0.022	0.002
METHYL ISOAMYL KETONE	4	0.051	0.205	0.016
METHYL ISOBUTYL KETONE	2.33	0.000	0.000	0.000
METHYL PROPYL KETONE	NA	0.000	0.000	0.000
NAPHTHA, NM&P	NA	0.000	0.000	0.000
NAPHTHALENE	26.45		0.000	0.000
NOX	NA	4.258	0.000	0.000
NITRIC ACID	26.4	0.000	0.000	0.000
NITROETHANE	NA	0.002	0.000	0.000
NITROPROPANE	14.4	0.000	0.006	0.000
OCTANE (n-)	0	0.037	0.000	0.000
ORGANIC ACIDS	NA	0.016	0.000	0.000
PENTANE (n-)	13.34	0.027	0.358	0.028
PHENOL	22.33	0.015	0.333	0.026
PHOSGENE	12.5		0.000	0.000
PHOSPHORIC ACID	30		0.000	0.000
PM	NA	4.390	0.000	0.000
PM-10	NA	0.292	0.000	0.000
PROPANE	NA	0.048	0.000	0.000
PROPYL ACETATE	NA	0.000	0.000	0.000
TOLUENE	2.04	0.088	0.180	0.014
TRICHLOROETHANE (METHYL CHLO	5.6	0.000	0.000	0.000
VINYL CHLORIDE	18.52	0.000	0.000	0.000
VOC	NA	10.085	0.000	0.000
XYLENE	2.1	0.031	0.065	0.005

NA = Not Available

# TERRESTRIAL TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	TERRESTRIAL		Factored Score	Normalized Factored Score
	TOXICITY Equiv. Factor	Inventory Value lb/FU		
Total Terr. Tox. Factored Score			2.049	1.906
Normalizing Score			1.075	
ACETALDEHYDE	3.255	0.031	0.103	0.095
ACETONE	1.860	0.005	0.010	0.009
ACETONITRILE	0.610	0.003	0.002	0.002
ALUMINUM	0.000	0.001	0.000	0.000
AMMONIA	9.030	0.001	0.006	0.005
ARSENIC	31.730	0.000	0.001	0.001
BENZENE	0.000	0.152	0.000	0.000
BUTYL ACETATE (n-)	0.000	0.000	0.000	0.000
BUTYL ALCOHOL	6.180	0.022	0.134	0.125
BUTYL CELLOSOLVE	7.590	0.000	0.000	0.000
BUTYLENE OXIDE, 1,2-	1.610	0.000	0.000	0.000
CADMIUM	21.030	0.006	0.121	0.112
CARBON TETRACHLORIDE	1.710	0.000	0.000	0.000
CHLORINE	0.000	0.510	0.000	0.000
CHLOROFORM	6.160	0.000	0.000	0.000
CHROMIUM, TRIVALENT	19.290	0.001	0.012	0.012
COBALT COMPOUNDS	20.960		0.000	0.000
COPPER COMPOUNDS	12.000	0.000	0.001	0.001
CUMENE	2.710	0.016	0.044	0.041
DICHLORODIFLUORMETHANE	1.330	0.001	0.001	0.001
DIETHYLMINETRIAMINE	5.270		0.000	0.000
ETHYL BENZENE	0.000	0.003	0.000	0.000
ETHYLENE	0.000	0.000	0.000	0.000
ETHYLENE DICHLORIDE	4.890		0.000	0.000
FGD SOLIDS	0.000	0.000	0.000	0.000
FLY ASH	0.000	0.000	0.000	0.000
FORMALDEHYDE	12.600	0.014	0.174	0.162
HEPTANE (n-)	9.500	0.055	0.526	0.490
HEXANE (n-)	0.000	0.043	0.000	0.000
HEXYL ACETATE	0.000	0.000	0.000	0.000
HEXAMETHYLENE DIISOCYANTE	2.640		0.000	0.000
HYDROCHLORIC ACID	5.740	0.001	0.008	0.007
HYDROGEN CYANIDE	30.000	0.005	0.147	0.137
IRON	0.000	0.000	0.000	0.000
ISOBUTYRALDEHYDE	1.860	0.257	0.478	0.445
ISOPROPYL ALCOHOL	0.950	0.000	0.000	0.000
KEROSENE	0.000	0.000	0.000	0.000
LEAD	5.750	0.002	0.012	0.011
METHYL ETHYL KETONE	1.860	0.016	0.030	0.028
METHYL ISOAMYL KETONE	2.050	0.051	0.105	0.098
METHYL ISOBUTYL KETONE	2.790	0.000	0.000	0.000

METHYL PROPYL KETONE	4.570	0.000	0.000	0.000
NAPHTHALENE	3.170	0.000	0.000	0.000
NITRIC ACID	10.200	0.000	0.005	0.004
NITROPROPANE, 2-	8.400		0.000	0.000
PHENOL	7.600	0.015	0.113	0.105
PHOSPHORIC ACID	5.400		0.000	0.000
PROPYL ACETATE	0.870	0.000	0.000	0.000
PLUTONIUM (FISSILE & NONFISSILE)	0.000	0.000	0.000	0.000
SLAG	0.000	0.000	0.000	0.000
SULFURIC ACID	3.600	0.000	0.000	0.000
TOLUENE	0.000	0.088	0.000	0.000
TRICHLOROETHANE (METHYL CHLOR	0.000	0.000	0.000	0.000
URANIUM (235, 236, 238)	NA	0.000	0.000	0.000
VINYL CHLORIDE	7.870	0.000	0.000	0.000
XYLENE	0.520	0.031	0.016	0.015
ZINC	0.000	0.000	0.000	0.000

NA = Not Available

## AQUATIC TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	AQUATIC TOXICITY	Inventory	Factored Score	Normalized Factored Score
	Equiv. Factor	Value lb/FU		
Total Aquatic Tox. Factored Score			2.250	2.554
Normalizing Score			0.881	
ACETONITRILE	0.000		0.000	0.000
AMMONIA	21.850		0.000	0.000
ALUMINUM	0.000	0.001	0.000	0.000
ARSENIC	18.750	0.000	0.000	0.000
BENZENE	14.070	0.000	0.006	0.007
BORON	0.000	0.010	0.000	0.000
BUTYL ALCOHOL	0.000	0.022	0.000	0.000
BUTYLENE OXIDE, 1,2-	NA		0.000	0.000
CADMIUM	36.250	0.006	0.208	0.237
CARBON TETRACHLORIDE	1.200		0.000	0.000
CHLORIDE	NA	7.351	0.000	0.000
CHLORINE	22.500	0.087	1.969	2.235
CHLOROFORM	9.750		0.000	0.000
CHROMIUM, TRIVALENT	16.630	0.001	0.011	0.012
COBALT COMPOUNDS	31.750		0.000	0.000
COPPER COMPOUNDS	30.000	0.000	0.001	0.002
DICHLORODIFLUOROMETHANE (CFC-1)	NA		0.000	0.000
HYDROCHLORIC ACID	13.860		0.000	0.000
IRON	25.000	0.000	0.000	0.000
LEAD	25.000	0.002	0.052	0.060
MERCURY	37.500	0.000	0.000	0.000
METHYL ISOAMYL KETONE	10.200		0.000	0.000
NAPHTHALENE	19.570		0.000	0.000
NITRIC ACID	15.600		0.000	0.000
NITROPROPANE, 2-	23.400		0.000	0.000
OIL & GREASE	NA	0.230	0.000	0.000
ORGANIC ACIDS	NA		0.000	0.000
PETROLEUM (CRUDE OIL)	NA	0.000	0.000	0.000
PHENOL	11.400	0.000	0.000	0.000
PHOSPHORIC ACID	11.400		0.000	0.000
SODIUM	NA	9.312	0.000	0.000
SULFIDE	NA	0.000	0.000	0.000
SULFURIC ACID	15.000	0.000	0.000	0.000
XYLENE	16.240		0.000	0.000
ZINC	20.300	0.000	0.001	0.001

NA = Not Available

## LAND USE IMPACT CALCULATIONS

<u>CHEMICAL NAME</u>	LAND USE Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total Land Use Score			237.170	1.497
Normalizing Score			161.615	
BOTTOM ASH	2.000	0.000	0.000	0.000
FGD SOLIDS	2.000	0.000	0.000	0.000
FLY ASH	2.000	0.000	0.000	0.000
HAZARDOUS WASTE	2.000	79.194	158.388	1.000
PLUTONIUM (FISSILE & NONFISSILE)	NA	0.000	0.000	0.000
SLAG	2.000	0.000	0.000	0.000
SOLID WASTE	1.500	52.521	78.782	0.497
URANIUM (235, 236, 238)	NA	0.000	0.000	0.000

NA = Not Available

**ALTERNATIVE THINNER**

## LIFE CYCLE IMPACT VALUATION CALCULATIONS

CARCOPT	Scale	Issues ----->	AHP Weighting Factor	Normalized Factored Score	Weighted Normalized Factored Score	Baseline Score
GLOBAL	ODP	0.17983	1.106	0.199	0.334	0.791
	GLBLWARM	0.11328	0.905	0.103	0.209	
	FSLFUELS	0.02855	1.133	0.032	0.074	
REGIONAL	ACIDDEP	0.06253	1.187	0.074	0.249	
	SMOG	0.13007	1.035	0.135	0.000	
	WTRUSE	0.01002		0.000		
LOCAL	TOXICITY	0.06155	1.999	0.123	0.209	
	HUMAN	0.02052	2.923	0.060	0.040	
	ENVTERR	0.02052	1.279	0.026		
	ENVAQ	0.02507	1.577			
	LANDUSE					

**OZONE DEPLETION POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	ODP Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total ODP Score			0.003	1.090
Normalizing Factor			0.003	
CARBON TETRACHLORIDE	1.080	0.003	0.003	1.000
DICHLORODIFLUOROMETHANE	1.000	0.000	0.000	0.000
TRICHLOROETHANE (METHYL CHLOROFORM)	0.120	0.002	0.000	0.090

**GLOBAL WARMING POTENTIAL IMPACT CALCULATIONS**

<b>CHEMICAL NAME</b>	<b>GWP Equiv. Factor</b>	<b>Inventory Value lb/FU</b>	<b>Factored Score</b>	<b>Normalized Factored Score</b>
Total GWP Score			271.890	0.905
Normalizing Score			300.337	
CARBON TETRACHLORIDE	1300	0.003	3.663	0.012
CO2	1	267.997	267.997	0.892
DICHLORODIFLUOROMETHANE	7100	0.000	0.000	0.000
TRICHLOROETHANE	100	0.002	0.229	0.001

## RESOURCE DEPLETION IMPACT CALCULATIONS

<u>CHEMICAL NAME</u>	<u>RESOURCE DEPLETION</u>	<u>Inventory</u>	<u>Factored Score</u>	<u>Normalized Factored Score</u>
	Equiv. Factor	Value lb/FU		
Total Resource Depetion Score			12,479.242	1.133
Normalizing Score			11,010.628	
BAUXITE	4	83.964	335.857	0.031
CHROME OXIDE	2	4.553	9.107	0.001
COAL	3	0.292	0.875	0.000
COBALT OXIDE	3	1.003	3.010	0.000
IRON ORE	3	1.282	3.845	0.000
LIMESTONE	1	4.653	4.653	0.000
MAGNESIUM ORE	1	2.249	2.249	0.000
NATURAL GAS	4	549.204	2,196.817	0.200
PETROLEUM (CRUDE OIL)	4	2,449.640	9,798.561	0.890
PHOSPHATE ROCK	3	2.092	6.276	0.001
SALT (SODIUM CHLORIDE)	1	43.084	43.084	0.004
SILICA	1	13.657	13.657	0.001
SODA ASH	1	2.624	2.624	0.000
THALLIUM	4		0.000	0.000
TITANIUM	3	8.412	25.235	0.002
URANIUM (235, 236, 238)	3	0.000	0.000	0.000
WATER INPUT	NA	40,071.312	0.000	0.000
ZINC	4	8.347	33.390	0.003

NA = Not Available

**ACIDIFICATION POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	Acid. Pot.	Inventory	Normalized	
	Equiv. Factor	Value lb/FU	Factored Score	Factored Score
Total Acid. Pot. Score			25.615	1.187
Normalizing Score			21.584	
AMMONIA	1.880	0.000	0.000	0.000
HYDROCHLORIC ACID	0.880	0.001	0.001	0.000
NOX	0.700	5.879	4.115	0.191
SOX	1.000	21.498	21.498	0.996

**PHOTOCHEMICAL OXIDANT POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	POCP Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total POCP Score			6.168	1.035
Normalizing Factor			5.959	
ACETALDEHYDE	0.527	0.054	0.029	0.005
ACETONE	0.178	0.007	0.001	0.000
ALDEHYDES	0.443	0.017	0.008	0.001
AROMATIC HYDROCARBONS (C8-C10)	0.761	0.023	0.017	0.003
BENZENE	0.189	0.110	0.021	0.003
BUTANE (n-)	0.410	0.053	0.022	0.004
BUTANE (iso-)	0.315	0.003	0.001	0.000
BUTYL ACETATE (n-)	0.323	0.139	0.045	0.008
BUTYL ALCOHOL	0.196	0.036	0.007	0.001
CHLOROFORM	0.021	0.001	0.000	0.000
ETHANE	0.082	0.042	0.003	0.001
ETHYL BENZENE	0.593	0.002	0.001	0.000
ETHYLENE	1.000	0.003	0.003	0.000
HEPTANE (n-)	0.529	0.076	0.040	0.007
HEXANE (n-)	0.421	0.059	0.025	0.004
METHANE	0.007	0.246	0.002	0.000
METHANOL	0.123	0.000	0.000	0.000
METHYL ETHYL KETONE	0.473	0.002	0.001	0.000
METHYL ISOAMYL KETONE	0.326	0.524	0.171	0.029
METHYL ISOBUTYL KETONE	0.326	0.023	0.008	0.001
METHYL PROPYL KETONE	0.326	0.000	0.000	0.000
OCTANE (n-)	0.493	0.051	0.025	0.004
PENTANE (n-)	0.408	0.037	0.015	0.003
PROPANE	0.420	0.066	0.028	0.005
PROPYL ACETATE	0.218	0.000	0.000	0.000
PROPYLENE	1.030	0.001	0.001	0.000
TOLUENE	0.563	0.024	0.014	0.002
TRICHLOROETHANE	0.021	0.002	0.000	0.000
VOC	0.397	14.210	5.641	0.947
XYLENE	0.849	0.047	0.040	0.007

# HUMAN HEALTH INHALATION TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	HH INHALATION		Factored Score	Normalized Factored Score
	TOXICITY Equiv. Factor	Inventory Value lb/FU		
Total HH Inh. Tox. Factored Score			25.416	1.999
Normalizing Score			12.715	
ACETALDEHYDE	7.44	0.054	0.404	0.032
ACETONE	0	0.007	0.000	0.000
ACETONITRILE	0	0.000	0.000	0.000
AMMONIA	5.7	0.000	0.000	0.000
ALDEHYDES	NA	0.017	0.000	0.000
ALUMINUM	15.6	0.003	0.041	0.003
AROMATIC HYDROCARBONS (C8-C10)	NA	0.023	0.000	0.000
BENZENE	NA	0.110	0.000	0.000
BUTANE (n-)	17.5	0.053	0.919	0.072
BUTANE (iso-)	NA	0.003	0.000	0.000
BUTYL ACETATE (n-)	8.49	0.139	1.177	0.093
BUTANOL	0.95	0.036	0.034	0.003
BUTYL CELLOSOLVE	12.29	0.000	0.000	0.000
BUTYLENE OXIDE, 1,2-	NA	0.000	0.000	0.000
CADMIUM	2.25		0.000	0.000
CARBON TETRACHLORIDE	7.06	0.003	0.020	0.002
CHLORINE	22.05	0.577	12.715	1.000
CHLOROFORM	2.57	0.001	0.003	0.000
CO	4.47	1.289	5.763	0.453
CO2	NA	267.997	0.000	0.000
CUMENE	1.35	0.027	0.036	0.003
CYCLOPARAFFINS, C-7	NA	0.011	0.000	0.000
CYCLOPARAFFINS, C-8	NA	0.004	0.000	0.000
DICHLORODIFLUOROMETHANE (CFC	0	0.000	0.000	0.000
ETHANE	NA	0.042	0.000	0.000
ETHYL BENZENE	3.19	0.002	0.007	0.001
ETHYLENE	0	0.003	0.000	0.000
ETHYLENE CHLORIDE	0	0.003	0.000	0.000
ETHYLENE DICHLORIDE	7.32	0.008	0.057	0.004
FLUORINE	14.64	0.028	0.410	0.032
FORMALDEHYDE	15.6	0.019	0.291	0.023
HEAVY AROMATIC	NA	0.197	0.000	0.000
HEPTANE (n-)	0	0.076	0.000	0.000
HEXYL ACETATE	NA	0.000	0.000	0.000
HEXAMETHYLENE DIISOCYANTE	10		0.000	0.000
HEXANE (n-)	0	0.059	0.000	0.000
HYDROCHLORIC ACID	14.82	0.001	0.020	0.002
HYDROGEN CYANIDE	30	0.007	0.202	0.016
ISOBUTYRALDEHYDE	1.86	0.000	0.000	0.000
ISOPROPYL ALCOHOL	0	0.002	0.000	0.000
LEAD	NA	0.001	0.000	0.000
METHANE	NA	0.246	0.000	0.000
METHANOL	0	0.000	0.000	0.000

METHYL ETHYL KETONE	1.4	0.002	0.003	0.000
METHYL ISOAMYL KETONE	4	0.524	2.098	0.165
METHYL ISOBUTYL KETONE	2.33	0.023	0.054	0.004
METHYL PROPYL KETONE	NA	0.000	0.000	0.000
NAPHTHA, NM&P	NA	0.066	0.000	0.000
NAPHTHALENE	26.45		0.000	0.000
NOX	NA	5.879	0.000	0.000
NITRIC ACID	26.4	0.000	0.000	0.000
NITROETHANE	NA	0.000	0.000	0.000
NITROPROPANE	14.4	0.000	0.000	0.000
OCTANE (n-)	0	0.051	0.000	0.000
ORGANIC ACIDS	NA	0.022	0.000	0.000
PENTANE (n-)	13.34	0.037	0.493	0.039
PHENOL	22.33	0.022	0.483	0.038
PHOSGENE	12.5		0.000	0.000
PHOSPHORIC ACID	30		0.000	0.000
PM	NA	5.948	0.000	0.000
PM-10	NA	0.310	0.000	0.000
PROPANE	NA	0.066	0.000	0.000
PROPYL ACETATE	NA	0.000	0.000	0.000
TOLUENE	2.04	0.024	0.049	0.004
TRICHLOROETHANE (METHYL CHLO	5.6	0.002	0.013	0.001
VINYL CHLORIDE	18.52	0.001	0.026	0.002
VOC	NA	14.210	0.000	0.000
XYLENE	2.1	0.047	0.098	0.008

NA = Not Available

## TERRESTRIAL TOXICITY IMPACT CALCULATIONS

## TERRESTRIAL

CHEMICAL NAME	TOXICITY Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total Terr. Tox. Factored Score			3.142	2.923
Normalizing Score			1.075	
ACETALDEHYDE	3.255	0.054	0.177	0.164
ACETONE	1.860	0.007	0.014	0.013
ACETONITRILE	0.610	0.000	0.000	0.000
ALUMINUM	0.000	0.001	0.000	0.000
AMMONIA	9.030	0.000	0.000	0.000
ARSENIC	31.730	0.000	0.001	0.001
BENZENE	0.000	0.111	0.000	0.000
BUTYL ACETATE (n-)	0.000	0.139	0.000	0.000
BUTYL ALCOHOL	6.180	0.036	0.220	0.205
BUTYL CELLOSOLVE	7.590	0.000	0.000	0.000
BUTYLENE OXIDE, 1,2-	1.610	0.000	0.000	0.000
CADMIUM	21.030	0.005	0.104	0.097
CARBON TETRACHLORIDE	1.710	0.003	0.005	0.004
CHLORINE	0.000	0.616	0.000	0.000
CHLOROFORM	6.160	0.001	0.008	0.008
CHROMIUM, TRIVALENT	19.290	0.001	0.011	0.010
COBALT COMPOUNDS	20.960		0.000	0.000
COPPER COMPOUNDS	12.000	0.000	0.000	0.000
CUMENE	2.710	0.027	0.073	0.068
DICHLORODIFLUOROMETHANE	1.330	0.000	0.000	0.000
DIETHYLMINETRIAMINE	5.270		0.000	0.000
ETHYL BENZENE	0.000	0.002	0.000	0.000
ETHYLENE	0.000	0.003	0.000	0.000
ETHYLENE DICHLORIDE	4.890		0.000	0.000
FGD SOLIDS	0.000	0.000	0.000	0.000
FLY ASH	0.000	0.000	0.000	0.000
FORMALDEHYDE	12.600	0.019	0.235	0.218
HEPTANE (n-)	9.500	0.076	0.725	0.674
HEXANE (n-)	0.000	0.059	0.000	0.000
HEXYL ACETATE	0.000	0.000	0.000	0.000
HEXAMETHYLENE DIISOCYANTE	2.640		0.000	0.000
HYDROCHLORIC ACID	5.740	0.001	0.008	0.007
HYDROGEN CYANIDE	30.000	0.007	0.202	0.188
IRON	0.000	0.000	0.000	0.000
ISOBUTYRALDEHYDE	1.860	0.000	0.000	0.000
ISOPROPYL ALCOHOL	0.950	0.002	0.002	0.002
KEROSENE	0.000	0.000	0.000	0.000
LEAD	5.750	0.003	0.015	0.014
METHYL ETHYL KETONE	1.860	0.002	0.004	0.004
METHYL ISOAMYL KETONE	2.050	0.524	1.075	1.000
METHYL ISOBUTYL KETONE	2.790	0.023	0.065	0.060

METHYL PROPYL KETONE	4.570	0.000	0.000	0.000
NAPHTHALENE	3.170	0.000	0.000	0.000
NITRIC ACID	10.200	0.000	0.000	0.000
NITROPROPANE, 2-	8.400	0.000	0.000	0.000
PHENOL	7.600	0.022	0.164	0.153
PHOSPHORIC ACID	5.400	0.000	0.000	0.000
PROPYL ACETATE	0.870	0.000	0.000	0.000
PLUTONIUM (FISSILE & NONFISSILE)	0.000	0.000	0.000	0.000
SLAG	0.000	0.000	0.000	0.000
SULFURIC ACID	3.600	0.000	0.000	0.000
TOLUENE	0.000	0.024	0.000	0.000
TRICHLOROETHANE (METHYL CHLOR	0.000	0.002	0.000	0.000
URANIUM (235, 236, 238)	NA	0.000	0.000	0.000
VINYL CHLORIDE	7.870	0.001	0.011	0.010
XYLENE	0.520	0.047	0.024	0.023
ZINC	0.000	0.000	0.000	0.000

NA = Not Available

## AQUATIC TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	AQUATIC TOXICITY Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total Aquatic Tox. Factored Score			1.127	1.279
Normalizing Score			0.881	
ACETONITRILE	0.000		0.000	0.000
AMMONIA	21.850		0.000	0.000
ALUMINUM	0.000	0.001	0.000	0.000
ARSENIC	18.750	0.000	0.000	0.001
BENZENE	14.070	0.001	0.009	0.010
BORON	0.000	0.013	0.000	0.000
BUTYL ALCOHOL	0.000	0.036	0.000	0.000
BUTYLENE OXIDE, 1,2-	NA		0.000	0.000
CADMIUM	36.250	0.005	0.179	0.203
CARBON TETRACHLORIDE	1.200		0.000	0.000
CHLORIDE	NA	10.123	0.000	0.000
CHLORINE	22.500	0.039	0.881	1.000
CHLOROFORM	9.750		0.000	0.000
CHROMIUM, TRIVALENT	16.630	0.001	0.009	0.010
COBALT COMPOUNDS	31.750		0.000	0.000
COPPER COMPOUNDS	30.000	0.000	0.001	0.001
DICHLORODIFLUOROMETHANE (CFC-1)	NA		0.000	0.000
HYDROCHLORIC ACID	13.860		0.000	0.000
IRON	25.000	0.000	0.000	0.000
LEAD	25.000	0.002	0.044	0.050
MERCURY	37.500	0.000	0.000	0.000
METHYL ISOAMYL KETONE	10.200		0.000	0.000
NAPHTHALENE	19.570		0.000	0.000
NITRIC ACID	15.600		0.000	0.000
NITROPROPANE, 2-	23.400		0.000	0.000
OIL & GREASE	NA	0.316	0.000	0.000
ORGANIC ACIDS	NA		0.000	0.000
PETROLEUM (CRUDE OIL)	NA	0.000	0.000	0.000
PHENOL	11.400	0.000	0.000	0.000
PHOSPHORIC ACID	11.400		0.000	0.000
SODIUM	NA	12.822	0.000	0.000
SULFIDE	NA	0.000	0.000	0.000
SULFURIC ACID	15.000	0.000	0.001	0.001
XYLENE	16.240		0.000	0.000
ZINC	20.300	0.000	0.001	0.001

NA = Not Available

## LAND USE IMPACT CALCULATIONS

<u>CHEMICAL NAME</u>	<u>LAND USE Equiv. Factor</u>	<u>Inventory Value lb/FU</u>	<u>Factored Score</u>	<u>Normalized Factored Score</u>
Total Land Use Score			254.813	1.577
Normalizing Score			161.615	
BOTTOM ASH	2.000	0.000	0.000	0.000
FGD SOLIDS	2.000	0.000	0.000	0.000
FLY ASH	2.000	0.000	0.000	0.000
HAZARDOUS WASTE	2.000	80.808	161.615	1.000
PLUTONIUM (FISSILE & NONFISSILE)	NA	0.000	0.000	0.000
SLAG	2.000	0.000	0.000	0.000
SOLID WASTE	1.500	62.132	93.198	0.577
URANIUM (235, 236, 238)	NA	0.000	0.000	0.000

NA = Not Available

**ALTERNATIVE PRIMER AND THINNER**

## LIFE CYCLE IMPACT VALUATION CALCULATIONS

CARCOPT	Scale	Issues ----->	AHP	Weighting Factor	Normalized Factored Score	Weighted Normalized Factored Score	Baseline Score
GLOBAL	ODP		0.17983	0.367	0.066	0.211	0.692
	GLBLWRM		0.11328	0.984	0.111		
	FSLFUELS		0.02855	1.180	0.034	0.203	
REGIONAL	ACIDDEP		0.06253	1.175	0.074		
	SMOG		0.13007	0.992	0.129		
	WTRUSE		0.01002		0.000	0.278	
LOCAL	TOXICITY	HUMAN	0.06155	1.739	0.107	0.238	
		ENVTERR	0.02052	2.862	0.059		
		ENVAQ	0.02052	3.540	0.073		
	LANDUSE		0.02507	1.585	0.040		

**OZONE DEPLETION POTENTIAL IMPACT CALCULATIONS**

CHEMICAL NAME	ODP Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total ODP Score			0.001	0.367
Normalizing Factor			0.003	
CARBON TETRACHLORIDE	1.080	0.000	0.000	0.000
DICHLORODIFLUOROMETHANE	1.000	0.001	0.001	0.367
TRICHLOROETHANE (METHYL CHLOROFORM)	0.120	0.000	0.000	0.000

**GLOBAL WARMING POTENTIAL IMPACT CALCULATIONS**

<b>CHEMICAL NAME</b>	<b>GWP Equiv. Factor</b>	<b>Inventory Value lb/FU</b>	<b>Factored Score</b>	<b>Normalized Factored Score</b>
Total GWP Score			295.468	0.984
Normalizing Score			300.337	
CARBON TETRACHLORIDE	1300	0.000	0.000	0.000
CO2	1	287.647	287.647	0.958
DICHLORODIFLUOROMETHANE	7100	0.001	7.821	0.026
TRICHLOROETHANE	100	0.000	0.000	0.000

## RESOURCE DEPLETION IMPACT CALCULATIONS

<u>CHEMICAL NAME</u>	<u>RESOURCE DEPLETION</u>	<u>Inventory</u>	<u>Factored Score</u>	<u>Normalized Factored Score</u>
	Equiv. Factor	Value lb/FU		
Total Resource Depetion Score			12,987.118	1.180
Normalizing Score			11,010.628	
BAUXITE	4	83.964	335.857	0.031
CHROME OXIDE	2	4.553	9.107	0.001
COAL	3	0.000	0.000	0.000
COBALT OXIDE	3	1.003	3.010	0.000
IRON ORE	3	1.341	4.023	0.000
LIMESTONE	1	4.653	4.653	0.000
MAGNESIUM ORE	1	2.249	2.249	0.000
NATURAL GAS	4	537.339	2,149.357	0.195
PETROLEUM (CRUDE OIL)	4	2,594.511	10,378.045	0.943
PHOSPHATE ROCK	3	0.000	0.000	0.000
SALT (SODIUM CHLORIDE)	1	43.470	43.470	0.004
SILICA	1	13.377	13.377	0.001
SODA ASH	1	2.624	2.624	0.000
THALLIUM	4		0.000	0.000
TITANIUM	3	13.782	41.345	0.004
URANIUM (235, 236, 238)	3	0.000	0.000	0.000
WATER INPUT	NA	40,765.310	0.000	0.000
ZINC	4	0.000	0.000	0.000

NA = Not Available

**ACIDIFICATION POTENTIAL IMPACT CALCULATIONS**

<b>CHEMICAL NAME</b>	<b>Acid. Pot.</b>	<b>Inventory</b>	<b>Normalized Factored</b>	
	<b>Equiv. Factor</b>	<b>Value lb/FU</b>	<b>Factored Score</b>	<b>Score</b>
Total Acid. Pot. Score			25.370	1.175
Normalizing Score			21.584	
AMMONIA	1.880	0.001	0.002	0.000
HYDROCHLORIC ACID	0.880	0.002	0.002	0.000
NOX	0.700	5.993	4.195	0.194
SOX	1.000	21.172	21.172	0.981

**PHOTOCHEMICAL OXIDANT POTENTIAL IMPACT CALCULATIONS**

<b>CHEMICAL NAME</b>	<b>POCP Equiv. Factor</b>	<b>Inventory Value lb/FU</b>	<b>Factored Score</b>	<b>Normalized Factored Score</b>
Total POCP Score			5.910	0.992
Normalizing Factor			5.959	
ACETALDEHYDE	0.527	0.006	0.003	0.001
ACETONE	0.178	0.008	0.001	0.000
ALDEHYDES	0.443	0.018	0.008	0.001
AROMATIC HYDROCARBONS (C8-C10)	0.761	0.061	0.046	0.008
BENZENE	0.189	0.275	0.052	0.009
BUTANE (n-)	0.410	0.056	0.023	0.004
BUTANE (iso-)	0.315	0.003	0.001	0.000
BUTYL ACETATE (n-)	0.323	0.024	0.008	0.001
BUTYL ALCOHOL	0.196	0.042	0.008	0.001
CHLOROFORM	0.021	0.000	0.000	0.000
ETHANE	0.082	0.045	0.004	0.001
ETHYL BENZENE	0.593	0.002	0.001	0.000
ETHYLENE	1.000	0.000	0.000	0.000
HEPTANE (n-)	0.529	0.081	0.043	0.007
HEXANE (n-)	0.421	0.063	0.026	0.004
METHANE	0.007	0.260	0.002	0.000
METHANOL	0.123	0.000	0.000	0.000
METHYL ETHYL KETONE	0.473	0.004	0.002	0.000
METHYL ISOAMYL KETONE	0.326	0.524	0.171	0.029
METHYL ISOBUTYL KETONE	0.326	0.000	0.000	0.000
METHYL PROPYL KETONE	0.326	0.000	0.000	0.000
OCTANE (n-)	0.493	0.054	0.027	0.004
PENTANE (n-)	0.408	0.039	0.016	0.003
PROPANE	0.420	0.070	0.029	0.005
PROPYL ACETATE	0.218	0.000	0.000	0.000
PROPYLENE	1.030	0.001	0.001	0.000
TOLUENE	0.563	0.189	0.106	0.018
TRICHLOROETHANE	0.021	0.000	0.000	0.000
VOC	0.397	13.327	5.291	0.888
XYLENE	0.849	0.047	0.040	0.007

# HUMAN HEALTH INHALATION TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	HH INHALATION			
	TOXICITY Equiv. Factor	Inventory Value lb/FU	Factored Score	Normalized Factored Score
Total HH Inh. Tox. Factored Score			22.109	1.739
Normalizing Score			12.715	
ACETALDEHYDE	7.44	0.006	0.046	0.004
ACETONE	0	0.008	0.000	0.000
ACETONITRILE	0	0.000	0.000	0.000
AMMONIA	5.7	0.001	0.005	0.000
ALDEHYDES	NA	0.018	0.000	0.000
ALUMINUM	15.6	0.003	0.043	0.003
AROMATIC HYDROCARBONS (C8-C10)	NA	0.061	0.000	0.000
BENZENE	NA	0.275	0.000	0.000
BUTANE (n-)	17.5	0.056	0.973	0.077
BUTANE (iso-)	NA	0.003	0.000	0.000
BUTYL ACETATE (n-)	8.49	0.024	0.205	0.016
BUTANOL	0.95	0.042	0.040	0.003
BUTYL CELLOSOLVE	12.29	0.000	0.000	0.000
BUTYLENE OXIDE, 1,2-	NA	0.000	0.000	0.000
CADMIUM	2.25		0.000	0.000
CARBON TETRACHLORIDE	7.06	0.000	0.000	0.000
CHLORINE	22.05	0.586	12.915	1.016
CHLOROFORM	2.57	0.000	0.000	0.000
CO	4.47	0.832	3.719	0.293
CO2	NA	287.647	0.000	0.000
CUMENE	1.35	0.023	0.030	0.002
CYCLOPARAFFINS, C-7	NA	0.011	0.000	0.000
CYCLOPARAFFINS, C-8	NA	0.004	0.000	0.000
DICHLORODIFLUOROMETHANE (CFC)	0	0.001	0.000	0.000
ETHANE	NA	0.045	0.000	0.000
ETHYL BENZENE	3.19	0.002	0.006	0.000
ETHYLENE	0	0.000	0.000	0.000
ETHYLENE CHLORIDE	0	0.000	0.000	0.000
ETHYLENE DICHLORIDE	7.32	0.000	0.000	0.000
FLUORINE	14.64	0.000	0.000	0.000
FORMALDEHYDE	15.6	0.020	0.314	0.025
HEAVY AROMATIC	NA	0.197	0.000	0.000
HEPTANE (n-)	0	0.081	0.000	0.000
HEXYL ACETATE	NA	0.005	0.000	0.000
HEXAMETHYLENE DIISOCYANTE	10		0.000	0.000
HEXANE (n-)	0	0.063	0.000	0.000
HYDROCHLORIC ACID	14.82	0.002	0.029	0.002
HYDROGEN CYANIDE	30	0.007	0.204	0.016
ISOBUTYRALDEHYDE	1.86	0.000	0.000	0.000
ISOPROPYL ALCOHOL	0	0.000	0.000	0.000
LEAD	NA	0.000	0.000	0.000
METHANE	NA	0.260	0.000	0.000
METHANOL	0	0.000	0.000	0.000

METHYL ETHYL KETONE	1.4	0.004	0.006	0.000
METHYL ISOAMYL KETONE	4	0.524	2.098	0.165
METHYL ISOBUTYL KETONE	2.33	0.000	0.000	0.000
METHYL PROPYL KETONE	NA	0.000	0.000	0.000
NAPHTHA, NM&P	NA	0.066	0.000	0.000
NAPHTHALENE	26.45		0.000	0.000
NOX	NA	5.993	0.000	0.000
NITRIC ACID	26.4	0.000	0.000	0.000
NITROETHANE	NA	0.004	0.000	0.000
NITROPROPANE	14.4	0.001	0.009	0.001
OCTANE (n-)	0	0.054	0.000	0.000
ORGANIC ACIDS	NA	0.023	0.000	0.000
PENTANE (n-)	13.34	0.039	0.523	0.041
PHENOL	22.33	0.021	0.461	0.036
PHOSGENE	12.5		0.000	0.000
PHOSPHORIC ACID	30		0.000	0.000
PM	NA	5.956	0.000	0.000
PM-10	NA	0.310	0.000	0.000
PROPANE	NA	0.070	0.000	0.000
PROPYL ACETATE	NA	0.000	0.000	0.000
TOLUENE	2.04	0.189	0.385	0.030
TRICHLOROETHANE (METHYL CHLO)	5.6	0.000	0.000	0.000
VINYL CHLORIDE	18.52	0.000	0.000	0.000
VOC	NA	13.327	0.000	0.000
XYLENE	2.1	0.047	0.099	0.008

NA = Not Available

## TERRESTRIAL TOXICITY IMPACT CALCULATIONS

CHEMICAL NAME	TERRESTRIAL		Factored Score	Normalized Factored Score
	TOXICITY Equiv. Factor	Inventory Value lb/FU		
Total Terr. Tox. Factored Score			3.077	2.862
Normalizing Score			1.075	
ACETALDEHYDE	3.255	0.006	0.020	0.019
ACETONE	1.860	0.008	0.015	0.014
ACETONITRILE	0.610	0.005	0.003	0.003
ALUMINUM	0.000	0.001	0.000	0.000
AMMONIA	9.030	0.001	0.008	0.007
ARSENIC	31.730	0.000	0.001	0.001
BENZENE	0.000	0.275	0.000	0.000
BUTYL ACETATE (n-)	0.000	0.024	0.000	0.000
BUTYL ALCOHOL	6.180	0.042	0.258	0.240
BUTYL CELLOSOLVE	7.590	0.000	0.000	0.000
BUTYLENE OXIDE, 1,2-	1.610	0.000	0.000	0.000
CADMIUM	21.030	0.008	0.168	0.156
CARBON TETRACHLORIDE	1.710	0.000	0.000	0.000
CHLORINE	0.000	0.707	0.000	0.000
CHLOROFORM	6.160	0.000	0.000	0.000
CHROMIUM, TRIVALENT	19.290	0.001	0.017	0.016
COBALT COMPOUNDS	20.960		0.000	0.000
COPPER COMPOUNDS	12.000	0.000	0.001	0.001
CUMENE	2.710	0.023	0.061	0.057
DICHLORODIFLUOROMETHANE	1.330	0.001	0.001	0.001
DIETHYLMINETRIAMINE	5.270		0.000	0.000
ETHYL BENZENE	0.000	0.002	0.000	0.000
ETHYLENE	0.000	0.000	0.000	0.000
ETHYLENE DICHLORIDE	4.890		0.000	0.000
FGD SOLIDS	0.000	0.000	0.000	0.000
FLY ASH	0.000	0.000	0.000	0.000
FORMALDEHYDE	12.600	0.020	0.253	0.236
HEPTANE (n-)	9.500	0.081	0.767	0.714
HEXANE (n-)	0.000	0.063	0.000	0.000
HEXYL ACETATE	0.000	0.005	0.000	0.000
HEXAMETHYLENE DIISOCYANTE	2.640		0.000	0.000
HYDROCHLORIC ACID	5.740	0.002	0.011	0.010
HYDROGEN CYANIDE	30.000	0.007	0.204	0.189
IRON	0.000	0.000	0.000	0.000
ISOBUTYRALDEHYDE	1.860	0.000	0.000	0.000
ISOPROPYL ALCOHOL	0.950	0.000	0.000	0.000
KEROSENE	0.000	0.000	0.000	0.000
LEAD	5.750	0.003	0.017	0.016
METHYL ETHYL KETONE	1.860	0.004	0.008	0.008
METHYL ISOAMYL KETONE	2.050	0.524	1.075	1.000
METHYL ISOBUTYL KETONE	2.790	0.000	0.000	0.000

METHYL PROPYL KETONE	4.570	0.000	0.000	0.000
NAPHTHALENE	3.170		0.000	0.000
NITRIC ACID	10.200	0.001	0.007	0.006
NITROPROPANE, 2-	8.400		0.000	0.000
PHENOL	7.600	0.021	0.157	0.146
PHOSPHORIC ACID	5.400		0.000	0.000
PROPYL ACETATE	0.870	0.000	0.000	0.000
PLUTONIUM (FISSILE & NONFISSILE)	0.000	0.000	0.000	0.000
SLAG	0.000	0.000	0.000	0.000
SULFURIC ACID	3.600	0.000	0.000	0.000
TOLUENE	0.000	0.189	0.000	0.000
TRICHLOROETHANE (METHYL CHLOR	0.000	0.000	0.000	0.000
URANIUM (235, 236, 238)	NA	0.000	0.000	0.000
VINYL CHLORIDE	7.870	0.000	0.000	0.000
XYLENE	0.520	0.047	0.025	0.023
ZINC	0.000	0.000	0.000	0.000

NA = Not Available

**AQUATIC TOXICITY IMPACT CALCULATIONS**

<b>CHEMICAL NAME</b>	<b>AQUATIC TOXICITY</b>	<b>Inventory</b>	<b>Factored Score</b>	<b>Normalized Factored Score</b>
	Equiv. Factor	Value lb/FU		
Total Aquatic Tox. Factored Score			3.119	3.540
Normalizing Score			0.881	
ACETONITRILE	0.000		0.000	0.000
AMMONIA	21.850		0.000	0.000
ALUMINUM	0.000	0.001	0.000	0.000
ARSENIC	18.750	0.000	0.001	0.001
BENZENE	14.070	0.001	0.009	0.011
BORON	0.000	0.014	0.000	0.000
BUTYL ALCOHOL	0.000	0.042	0.000	0.000
BUTYLENE OXIDE, 1,2-	NA		0.000	0.000
CADMUM	36.250	0.008	0.289	0.328
CARBON TETRACHLORIDE	1.200		0.000	0.000
CHLORIDE	NA	10.721	0.000	0.000
CHLORINE	22.500	0.121	2.727	3.096
CHLOROFORM	9.750		0.000	0.000
CHROMIUM, TRIVALENT	16.630	0.001	0.015	0.017
COBALT COMPOUNDS	31.750		0.000	0.000
COPPER COMPOUNDS	30.000	0.000	0.002	0.002
DICHLORODIFLUOROMETHANE (CFC-1	NA		0.000	0.000
HYDROCHLORIC ACID	13.860		0.000	0.000
IRON	25.000	0.000	0.000	0.000
LEAD	25.000	0.003	0.073	0.082
MERCURY	37.500	0.000	0.000	0.000
METHYL ISOAMYL KETONE	10.200		0.000	0.000
NAPHTHALENE	19.570		0.000	0.000
NITRIC ACID	15.600		0.000	0.000
NITROPROPANE, 2-	23.400		0.000	0.000
OIL & GREASE	NA	0.335	0.000	0.000
ORGANIC ACIDS	NA		0.000	0.000
PETROLEUM (CRUDE OIL)	NA	0.000	0.000	0.000
PHENOL	11.400	0.000	0.000	0.000
PHOSPHORIC ACID	11.400		0.000	0.000
SODIUM	NA	13.580	0.000	0.000
SULFIDE	NA	0.000	0.000	0.000
SULFURIC ACID	15.000	0.000	0.001	0.001
XYLENE	16.240		0.000	0.000
ZINC	20.300	0.000	0.001	0.002

NA = Not Available

LAND USE IMPACT CALCULATIONS

CHEMICAL NAME	LAND USE EQUIV. FACTOR	INVENTORY VALUE LB/FU	FACTORED SCORE	NORMALIZED FACTORED SCORE
Total Land Use Score			251.871	1.585
Normalizing Score			161.615	
BOTTOM ASH	2.000	0.000	0.000	0.000
FGD SOLIDS	2.000	0.000	0.000	0.000
FLY ASH	2.000	0.000	0.000	0.000
HAZARDOUS WASTE	2.000	79.465	158.930	1.000
PLUTONIUM (FISSILE & NONFISSILE)	NA	0.000	0.000	0.000
SLAG	2.000	0.000	0.000	0.000
SOLID WASTE	1.500	61.961	92.941	0.585
URANIUM (235, 236, 238)	NA	0.000	0.000	0.000

NA = Not Available

**APPENDIX E**  
**SENSITIVITY ANALYSIS**

**Table E-1**

Compound	Environmental Compartment	Current Equivalency Factors			GWP	HHT	Terr	Aqua	Land	Res
VOC	Air	POCP	ODP	AP						
Heavy aromatics	Air			0.761						
Aromatic hydrocarbons	Air									
C7 cycloparaffins	Air									
C8 cycloparaffins	Air									
Hydrocarbons	Air									
Organic acids	Air									
Aliphatic hydrocarbons	Air									
Mobile ions	Water									
Dissolved solids	Water									
Metals	Water									

Worst Case Equivalency Factors Derived from Tabulated Equivalency Factors										
Compound	Environmental Compartment	POCP	ODP	AP	GWP	HHT	Terr	Aqua	Land	Res
VOC	Air	1.03								
Heavy aromatics	Air		1.03							
Aromatic hydrocarbons	Air									
C7 cycloparaffins	Air									
C8 cycloparaffins	Air									
Hydrocarbons	Air			1.03						
Organic acids	Air									
Aliphatic hydrocarbons	Air									
Mobile ions	Water									
Dissolved solids	Water									
Metals	Water									

Environmental Compartment	POCP	ODP	AP	GWP	HHT	Terr	Aqua	Land	Res	% Change
Air	5.959	0.003	21.584	300.337	12.715	1.075	0.881	161.615	11010.63	
	0.13007	0.17983	0.06253	0.11328	0.06155	0.02052	0.02052	0.02507	0.02855	
Normalizing Factors										
AHP Weighting Factors										
Total Normalized Fact. Sc. - Scenario 1	1.114	1.09	1.198	1.013	2.15	3.799	1.28	1.577	1.263	0.842724
Revised Total Norm. Fact. Sc - Scen 1	1.652084	1.09	1.198	1.013	1.305836	1.258577	1.00148	1.577	1.269755	0.803102
Total Normalized Fact. Sc. - Scenario 2	0.993	0.367	1.173	0.927	1.612	2.635	3.537	1.585	1.121	0.671124
Revised Normalized Fact. Sc. Scen 2	1.506585	0.367	1.173	0.927	1.189616	1.15297	0.8889067	1.585	1.127214	0.627359
Total Normalized Fact. Sc. - Scenario 3	0.8	0.799	1.116	0.739	1.51	2.565	0.925	1.493	0.929	0.629745
Revised Normalized Fact. Sc. - Scen 3	1.196015	0.799	1.116	0.739	0.946338	0.912561	0.730384	1.493	0.933904	0.6088
Total Normalized Fact. Sc. - Scenario 4	0.721	0.265	1.098	0.677	1.172	1.906	2.554	1.497	0.827	0.51158
Revised Normalized Fact. Sc. - Scen. 4	1.093978	0.265	1.098	0.677	0.863833	0.837134	0.64922	1.497	0.831512	0.480236
Total Normalized Fact. Sc. - Scenario 5	1.035	1.09	1.187	0.905	1.1999	2.923	1.279	1.577	1.133	0.788525
Revised Normalized Fact. Sc. - Scen 5	1.54396	1.09	1.187	0.905	1.223262	1.175859	0.891411	1.577	1.13933	0.763355
Total Normalized Fact. Sc. - Scenario 6	0.992	0.367	1.175	0.984	1.1739	2.862	3.54	1.585	1.118	0.6911797
Revised Normalized Fact. Sc. - Scen. 6	1.482657	0.367	1.175	0.984	1.170204	1.130781	0.946664	1.585	1.186086	0.632041

Compound	Environmental Compartment	POCP	ODP	AP	GWP	HHT	Terr	Aqua	Land	Res
VOC	Air	5.959								
Heavy aromatics	Air									



<b>Metals</b>	Water	0	0	0	0	0	0	0	1.9E-11	0	1.4E-13
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Compound	Environmental Compartment	Current Factored Score - Scenario 2						Res
		POCP	ODP	AP	GWP	HHIT	Terr	
VOC	Air	5.516					0	
Heavy aromatics	Air						0	
Aromatic hydrocarbons	Air		0.029				0	
C7 cycloparaffins	Air						0	
C8 cycloparaffins	Air						0	
Hydrocarbons	Air						0	
Organic acids	Air						0	
Aliphatic hydrocarbons	Air						0	
Mobile ions	Water							
Dissolved solids	Water							
Metals	Water							

Compound	Environmental Compartment	Current Emissions Rates - Scenario 2						Res
		POCP	ODP	AP	GWP	HHIT	Terr	
VOC	Air	13.89406						
Heavy aromatics	Air	0.197299						
Aromatic hydrocarbons	Air	0.038055						
C7 cycloparaffins	Air	0.010686						
C8 cycloparaffins	Air	0.003907						
Hydrocarbons	Air	2.93879						
Organic acids	Air	0.021765						
Aliphatic hydrocarbons	Air	0						
Mobile ions	Water	30.87066						
Dissolved solids	Water	6.3E-07						
Metals	Water	3.5E-10						

Compound	Environmental Compartment	Revised Factored Score - Scenario 2						Res
		POCP	ODP	AP	GWP	HHIT	Terr	
VOC	Air	14.31088	0	0	0	367.4979	175.0652	0
Heavy aromatics	Air	0	0	0	0	5.218559	2.485967	0
Aromatic hydrocarbons	Air	0.039197	0	0	0	1.006555	0.479493	0
C7 cycloparaffins	Air	0	0	0	0	0.282645	0.134644	0
C8 cycloparaffins	Air	0	0	0	0	0.10334	0.049228	0
Hydrocarbons	Air	3.026954	0	0	0	77.731	37.02875	0
Organic acids	Air	0	0	0	0	0	0	0.015628
Aliphatic hydrocarbons	Air	0	0	0	0	0	0	0.1175516
Mobile ions	Water	0	0	0	0	0	0	0
Dissolved solids	Water	0	0	0	0	0	0	0
Metals	Water	0	0	0	0	0	0	0

Compound	Environmental Compartment	Revised Normalized Factored Score - Scenario 2						Res
		POCP	ODP	AP	GWP	HHIT	Terr	
VOC	Air	0.925572	0	0	0	0.925572	0.925572	0
Heavy aromatics	Air	0	0	0	0	0.013143	0.013143	0
Aromatic hydrocarbons	Air	0.002535	0	0	0	0.002535	0.002535	0

C7 cycloparaffins	Air	0	0	0	0	0.000712	0.000712	0	0	0	3.9E-06
C8 cycloparaffins	Air	0	0	0	0	0.00026	0.00026	0	0	0	1.4E-06
Hydrocarbons	Air	<b>0.195771</b>	0	0	0	0.195771	0.195771	0	0	0	0.001068
Organic acids	Air	0	0	0	0	0	0	0	0	0	7.9E-06
Aliphatic hydrocarbons	Air	0	0	0	0	0	0	0	0	0	0
Mobile ions	Water	0	0	0	0	0	0	0	0	0	0
Dissolved solids	Water	0	0	0	0	0	0	0	0	0	0
Metals	Water	0	0	0	0	0	0	0	0	0	1.3E-13

Compound	Environmental Compartment	Current Factored Score - Scenario 3	POCP	ODP	AP	GWP	HHIT	Terr	Aqua	Land	Res
VOC	Air	4.324						0			
Heavy aromatics	Air							0			
Aromatic hydrocarbons	Air							0			
C7 cycloparaffins	Air							0			
C8 cycloparaffins	Air							0			
Hydrocarbons	Air							0			
Organic acids	Air							0			
Aliphatic hydrocarbons	Air							0			
Mobile ions	Water							0			
Dissolved solids	Water							0			
Metals	Water							0			

Compound	Environmental Compartment	Current Emissions Rates - Scenario 3	POCP	ODP	AP	GWP	HHIT	Terr	Aqua	Land	Res
VOC	Air	10.89153									
Heavy aromatics	Air	0.14245									
Aromatic hydrocarbons	Air	0.01203									
C7 cycloparaffins	Air	0.008807									
C8 cycloparaffins	Air	0.00322									
Hydrocarbons	Air	2.421871									
Organic acids	Air	0.017937									
Aliphatic hydrocarbons	Air	0									
Mobile ions	Water	25.44066									
Dissolved solids	Water	5.0E-07									
Metals	Water	2.7E-10									

Compound	Environmental Compartment	Revised Factored Score - Scenario 3	POCP	ODP	AP	GWP	HHIT	Terr	Aqua	Land	Res
VOC	Air	11.21828	0	0	0	0	288.081	137.2333	0	0	43.56612
Heavy aromatics	Air	0	0	0	0	0	376.7803	179.487	0	0	0.5698
Aromatic hydrocarbons	Air	0.012391	0	0	0	0	0.318194	0.151578	0	0	0.04812
C7 cycloparaffins	Air	0	0	0	0	0	0.232945	0.110968	0	0	0.035228
C8 cycloparaffins	Air	0	0	0	0	0	0.085169	0.040572	0	0	0.01288
Hydrocarbons	Air	2.494527	0	0	0	0	64.05849	30.51557	0	0	9.687484
Organic acids	Air	0	0	0	0	0	0	0	0	0	0.071748
Aliphatic hydrocarbons	Air	0	0	0	0	0	0	0	0	0	0
Mobile ions	Water	0	0	0	0	0	0	0	0	0	0
Dissolved solids	Water	0	0	0	0	0	0	0	0	0	0

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Metals	Water	Environmental Compartment	Revised Normalized Factored Score - Scenario 3							Res
Compound		POCP	ODP	AP	GWP	HHIT	Terr	Aqua	Land	0.003957
VOC	Air	0.725554	0	0	0	0.725554	0.725554	0	0	0.00052
Heavy aromatics	Air	0	0	0	0	0.009489	0.009489	0	0	4.4E-06
Aromatic hydrocarbons	Air	0.000801	0	0	0	0.000801	0.000801	0	0	3.2E-06
C7 cycloparaffins	Air	0	0	0	0	0.000587	0.000587	0	0	1.2E-06
C8 cycloparaffins	Air	0	0	0	0	0.000215	0.000215	0	0	0.00088
Hydrocarbons	Air	0.161336	0	0	0	0.161336	0.161336	0	0	6.5E-06
Organic acids	Air	0	0	0	0	0	0	0	0	0
Aliphatic hydrocarbons	Air	0	0	0	0	0	0	0	0	0
Mobile ions	Water	0	0	0	0	0	0	0	0	0
Dissolved solids	Water	0	0	0	0	0	0	0	0	0
Metals	Water	0	0	0	0	0	0	0	0	9.8E-14

Compound	Environmental Compartment	Current Factored Score - Scenario 4							Res
VOC	Air	POCP	ODP	AP	GWP	HHIT	Terr	Aqua	Land
Heavy aromatics	Air	4.324	0	0	0	0	0	0	0
Aromatic hydrocarbons	Air	0.015	0	0	0	0	0	0	0
C7 cycloparaffins	Air	0	0	0	0	0	0	0	0
C8 cycloparaffins	Air	0	0	0	0	0	0	0	0
Hydrocarbons	Air	0	0	0	0	0	0	0	0
Organic acids	Air	0	0	0	0	0	0	0	0
Aliphatic hydrocarbons	Air	0	0	0	0	0	0	0	0
Mobile ions	Water	0	0	0	0	0	0	0	0
Dissolved solids	Water	0	0	0	0	0	0	0	0
Metals	Water	0	0	0	0	0	0	0	0

Compound	Environmental Compartment	Current Emissions Rates - Scenario 4							Res
VOC	Air	POCP	ODP	AP	GWP	HHIT	Terr	Aqua	Land
Heavy aromatics	Air	10.08484	0	0	0	0	0	0	0
Aromatic hydrocarbons	Air	0.14245	0	0	0	0	0	0	0
C7 cycloparaffins	Air	0.019837	0	0	0	0	0	0	0
C8 cycloparaffins	Air	0.007804	0	0	0	0	0	0	0
Hydrocarbons	Air	0.002853	0	0	0	0	0	0	0
Organic acids	Air	2.146092	0	0	0	0	0	0	0
Aliphatic hydrocarbons	Air	0.015894	0	0	0	0	0	0	0
Mobile ions	Water	22.54372	0	0	0	0	0	0	0
Dissolved solids	Water	4.6E-07	0	0	0	0	0	0	0
Metals	Water	5.0E-10	0	0	0	0	0	0	0

Compound	Environmental Compartment	Revised Factored Score - Scenario 4							Res
VOC	Air	POCP	ODP	AP	GWP	HHIT	Terr	Aqua	Land
Heavy aromatics	Air	10.38739	0	0	0	0	266.744	127.069	0
Aromatic hydrocarbons	Air	0	0	0	0	0	3.767803	1.79487	0

C7 cycloparaffins	Air	0	0	0.206416	0.09833	0	0	0.031216
C8 cycloparaffins	Air	0	0	0.075462	0.035948	0	0	0.011412
Hydrocarbons	Air	0	0	56.76413	27.04076	0	0	8.584368
Organic acids	Air	0	0	0	0	0	0	0.063576
Aliphatic hydrocarbons	Air	0	0	0	0	0	0	0
Mobile ions	Water	0	0	0	0	0	0	0
Dissolved solids	Water	0	0	0	0	0	0	0
Metals	Water	0	0	0	0	0	0	2.0E-09
						0	0	1.9E-08

Compound	Current Factored Score - Scenario 5						Res
	POCP	ODP	AP	GWP	HHiT	Terr	
VOC	5.641					0	
Heavy aromatics	Air					0	
Aromatic hydrocarbons	Air					0	
C7 cycloparaffins	Air					0	
C8 cycloparaffins	Air					0	
Hydrocarbons	Air					0	
Organic acids	Air					0	
Aliphatic hydrocarbons	Air					0	
Mobile ions	Water					0	
Dissolved solids	Water					0	
Metals	Water					0	

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Metals	Water	Environmental Compartment	Revised Factored Score - Scenario 5						Land	Res
			POCP	ODP	AP	GWP	HHIT	Terr		
VOC	Air	Air	14.63629	0	0	0	375.8542	179.0459	0	58.83996
Heavy aromatics	Air	Air	0	0	0	0	5.218559	2.485987	0	0.789196
Aromatic hydrocarbons	Air	Air	0.023613	0	0	0	0.606366	0.288855	0	0.0917
C7 cycloparaffins	Air	Air	0	0	0	0	0.284232	0.1354	0	0.042984
C8 cycloparaffins	Air	Air	0	0	0	0	0.103922	0.049505	0	0.015716
Hydrocarbons	Air	Air	3.0439	0	0	0	78.16818	37.23606	0	11.82097
Organic acids	Air	Air	0	0	0	0	0	0	0	0.087548
Aliphatic hydrocarbons	Air	Air	0.000836	0	0	0	0.044833	0.021357	0	0.00678
Mobile ions	Water	Water	0	0	0	0	0	0	0	0
Dissolved solids	Water	Water	0	0	0	0	0	0	0	0
Metals	Water	Water	0	0	0	0	0	0	0	1.4E-09
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Metals	Water	Environmental Compartment	Revised Normalized Factored Score - Scenario 5						Land	Res
			POCP	ODP	AP	GWP	HHIT	Terr		
VOC	Air	Air	0.946618	0	0	0	0.946618	0.946618	0	0.005162
Heavy aromatics	Air	Air	0	0	0	0	0.013143	0.013143	0	0.000072
Aromatic hydrocarbons	Air	Air	0.001527	0	0	0	0.001527	0.001527	0	8.3E-06
C7 cycloparaffins	Air	Air	0	0	0	0	0	0.000716	0.000716	0
C8 cycloparaffins	Air	Air	0	0	0	0	0	0.000262	0.000262	0
Hydrocarbons	Air	Air	0.196867	0	0	0	0	0.196867	0.196867	0
Organic acids	Air	Air	0	0	0	0	0	0	0	0.001074
Aliphatic hydrocarbons	Air	Air	0.000054	0	0	0	0	0.000113	0.000113	0
Mobile ions	Water	Water	0	0	0	0	0	0	0	6.2E-07
Dissolved solids	Water	Water	0	0	0	0	0	0	0	0
Metals	Water	Water	0	0	0	0	0	0	0	1.3E-13
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Metals	Water	Environmental Compartment	Current Factored Score - Scenario 6						Land	Res
			POCP	ODP	AP	GWP	HHIT	Terr		
VOC	Air	Air	5.291	0	0	0	0	0	0	0
Heavy aromatics	Air	Air	0.046	0	0	0	0	0	0	0
Aromatic hydrocarbons	Air	Air	0	0	0	0	0	0	0	0
C7 cycloparaffins	Air	Air	0	0	0	0	0	0	0	0
C8 cycloparaffins	Air	Air	0	0	0	0	0	0	0	0
Hydrocarbons	Air	Air	0	0	0	0	0	0	0	0
Organic acids	Air	Air	0	0	0	0	0	0	0	0
Aliphatic hydrocarbons	Air	Air	0	0	0	0	0	0	0	0
Mobile ions	Water	Water	0	0	0	0	0	0	0	0
Dissolved solids	Water	Water	0	0	0	0	0	0	0	0
Metals	Water	Water	0	0	0	0	0	0	0	0
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Metals	Water	Environmental Compartment	Current Emissions Rates - Scenario 6						Land	Res
			Air	Air	Air	Air	Air	Air		
VOC	Air	Air	13.32696	0	0	0	0	0	0	0
Heavy aromatics	Air	Air	0.197299	0	0	0	0	0	0	0
Aromatic hydrocarbons	Air	Air	0.060582	0	0	0	0	0	0	0

Compound		Revised Factored Score - Scenario 6						Revised Normalized Factored Score - Scenario 6											
	Environmental Compartment	POCP	ODP	AP	GWP	HHIT	Terr	Aqua	Land	Res	POCP	ODP	AP	GWP	HHIT	Terr	Aqua	Land	Res
VOC	Air	13.72677	0	0	0	0	352.4981	167.9197	0	0	0.887793	0.887793	0	0	0	0	0	0	0.004841
Heavy aromatics	Air	0	0	0	0	0	5.218559	2.485967	0	0	0	0	0	0	0	0	0	0	0.789196
Aromatic hydrocarbons	Air	0.062399	0	0	0	0	1.602394	0.763333	0	0	0	0	0	0	0	0	0	0	0.242328
C7 cycloparaffins	Air	0	0	0	0	0	0.301027	0.143401	0	0	0	0	0	0	0	0	0	0	0.045524
C8 cycloparaffins	Air	0	0	0	0	0	0.110058	0.052429	0	0	0	0	0	0	0	0	0	0	0.016644
Hydrocarbons	Air	3.2223863	0	0	0	0	82.78755	39.43755	0	0	0	0	0	0	0	0	0	0	12.51986
Organic acids	Air	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.092724
Aliphatic hydrocarbons	Air	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mobile ions	Water	0	0	0	0	0	0	0	0	0	0	0	0	0	718.4031	0	0	0	0
Dissolved solids	Water	0	0	0	0	0	0	0	0	0	0	0	0	0	9.8E-06	0	0	0	0
Metals	Water	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3E-08	0	0	0	1.4E-09